AD NUMBER
AD907828
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to U.S. Gov't. agencies only; Test and Evaluation; OCT 1972. Other requests shall be referred to Air Force Armament Laboratory, Attn: DLDG, Eglin AFB, FL 32542.**
AUTHORITY
AFATL ltr dtd 23 Jan 1976

AFATL-TR-72-201

DEVELOPMENT OF 20MM AND 30MM PLASTIC/ALUMINUM CARTRIDGE CASES

AAI CORPORATION

TECHNICAL REPORT AFATL-TR-72-201

OCTOBER 1972

Distribution limited to U. S. Government agencies only; this report documents test and evaluation; distribution limitation applied October 1972. Other requests for this document must be referred to the Air Force Armament Laboratory (DLDG), Eglin Air Force Base, Florida 32542.

AIR FORCE ARMAMENT LABORATORY

AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE

EGLIN AIR FORCE BASE, FLORIDA

Development Of 20mm And 30mm Plastic/Aluminum Cartridge Cases

Matthew G. Popik

Robert W. Schnepfe

FOREWORD

This report documents work on the 20mm and 30mm Plastic/Aluminum Cartridge cases, performed during the period 1 March 1970 to 30 September 1972 by AAI Corporation, Cockeysville, Maryland, under Contract F08635-70-C-0067 with the Air Force Armament Laboratory, Eglin Air Force Base, Florida. The Project Engineers for the Armament Laboratory were Mr. David G. Uhrig (DLDG) and Major Stephen J. Bilsbury (DLDG).

The report has been assigned AAI Corporation Engineering Report Number ER-7250.

This technical report has been reviewed and is approved.

DALE M. DAVIS
Director, Guns and Rockets Division

ABSTRACT

Basic feasibility was established for the 20mm and 30mm plastic/aluminum cartridge cases under this program. The case design consists of a plastic body joined mechanically to an aluminum base forming a composite assembly. Work on the 30mm case was limited to Mann barrel firings while the 20mm case was fired successfully in both a Mann barrel and the M61 automatic gun at a rate of 4300 rounds per minute. Test firings of the 20mm case in the M39 gun, however, were unsuccessful. The effort on the 20mm case progressed into a development program including high and low temperature firings in the M61. Satisfactory case performance has been established at the temperature extremes (160°F and -65°F) and ambient temperatures with the case design being developed as far as poss le within the scope of this contract.

Distribution limited to U. S. Government agencies only; this report documents test and evaluation; distribution limitation applied October 1972. Other requests for this document must be referred to the Air Force Armament Laboratory (DLDG), Eglin Air Force Base, Florida 32542.

(The reverse of this page is blank)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION I

INTRODUCTION

The primary objective of this program was to establish basic feasibility for plastic/aluminum cartridge cases in 20mm and 30mm sizes. The 20mm cartridge case was to be patterned after the brass M103 case to be compatible with existing weapons and to eventually serve as a replacement for the M103 case. The 20mm case was test fired in the M61 cannon and in a Mann barrel. The 30mm cartridge case is a new design which was evolved to achieve certain performance requirements. No weapon for this munition currently exists in the inventory; therefore, testing was accomplished in a specially constructed Mann barrel.

At the request of the AFATL project engineer, a short burst of 20mm plastic/aluminum case rounds were fired in the M39 gun. These tests were unsuccessful as the cases were damaged by the sharp, intermittent feed motion of the gun system. Those few rounds that were chambered intact were fired and extracted properly.

The 20mm and 30mm plastic/aluminum cartridge cases are both of the same basic design which consists of an aluminum base joined to a plastic body. The use of these materials represents a sizeable weight reduction over a comparable case of brass. The standard M103 brass 20mm cartridge case is over three times as heavy as the plastic/aluminum case developed in this effort. The weight difference between the assembled munitions utilizing brass and plastic/aluminum cases is 0.186 lb per round. When the number of rounds carried by various aircraft is considered, the payload weight savings is significant. The following list gives typical examples of the weight savings that may be expected with various aircraft using 20mm ammunition:

Aircraft	Number of Rounds	Weight Saved
F-111	2084	388 lb
F-4E	638	119 lb
F-105	1200	223 lb
AC-130 Gunship	6000	1116 lb
A-7D	1000	186 lb

In addition to weight improvement, a significant advantage is realized with the use of plastic/aluminum cases in that a critical and expensive material (brass) is replaced by non-critical and inexpensive materials.

The main program objective, establishment of basic feasibility, was satisfied early in the program with the successful test firing of the 30mm case in the Mann barrel and the 20mm case in the M61 cannon at ambient temperature. Therefore, the majority of the effort was concentrated in refinement of the design and, in particular, the achievement of proper performance of the 20mm case at temperature extremes in the M61 cannon.

Included in this report is a description of each of the cartridge cases, explanation of test methods, a narrative describing the developmental testing, conclusions and recommendations, and appendixes which contain drawings of the molds and case component details.

SECTION II

DESIGN DESCRIPTIONS

1. 20MM CARTRIDGE CASE

a. PHYSICAL DESCRIPTION

The 20mm cartridge case is a two-piece composite consisting of a plastic body and an aluminum base. The two pieces are mechanically joined by mating buttress-shaped teeth which snap into place when the plastic body is pressed into the base. The plastic body extends inside the base and insulates the thin-walled aluminum section from contact with the hot propellant gases. Figure 1 shows the 20mm plastic/aluminum case.

The final design of the 20mm case joint contains two buttresses for mechanically joining the plastic body and the aluminum base. The molded buttresses of the plastic body are a press fit of 0.010 to 0.015 inch on the diameter with the corresponding surfaces in the base. At assembly, the plastic body is pressed into the base and the teeth snap into place. The fit on the plastic provides a firm joint that resists rotational slippage and forms a watertight seal. On firing, the plastic inside the aluminum base obturates by internal gas pressure against the base, thus sealing the joint area from gas leakage. The joint design allows some relative movement between the two parts in a lengthwise direction. If a longitudinal compressive force is applied to the case, there will be some rearward movement of the plastic body inside the aluminum base. The case is made approximately 0.010 inch longer than standard so that at chambering the case will be compressed and shortened by that amount. At firing, the bolt deflection that occurs at peak pressure can then be taken up by that amount of compression before any tensile loads are applied to the joint area. This serves to reduce the stress levels in the case that may occur from axial tension caused by bolt deflection and decreases the possibility of failure at the joint.

The base of the cartridge case is subjected to the most severe internal stresses of any part of the case. The extractor groove area is unsupported by the chamber and must withstand the stresses caused by internal gas pressure. Tests have shown 7075-T6 aluminum alloy to be the material best suited for this purpose since it has the required mechanical properties to withstand the high stresses imposed at firing. In addition, the low density of aluminum makes it attractive from a weight standpoint. A detail print of the cartridge base, AAI Drawing No. 535[illegible]-40001, is presented in Appendix I of this report.

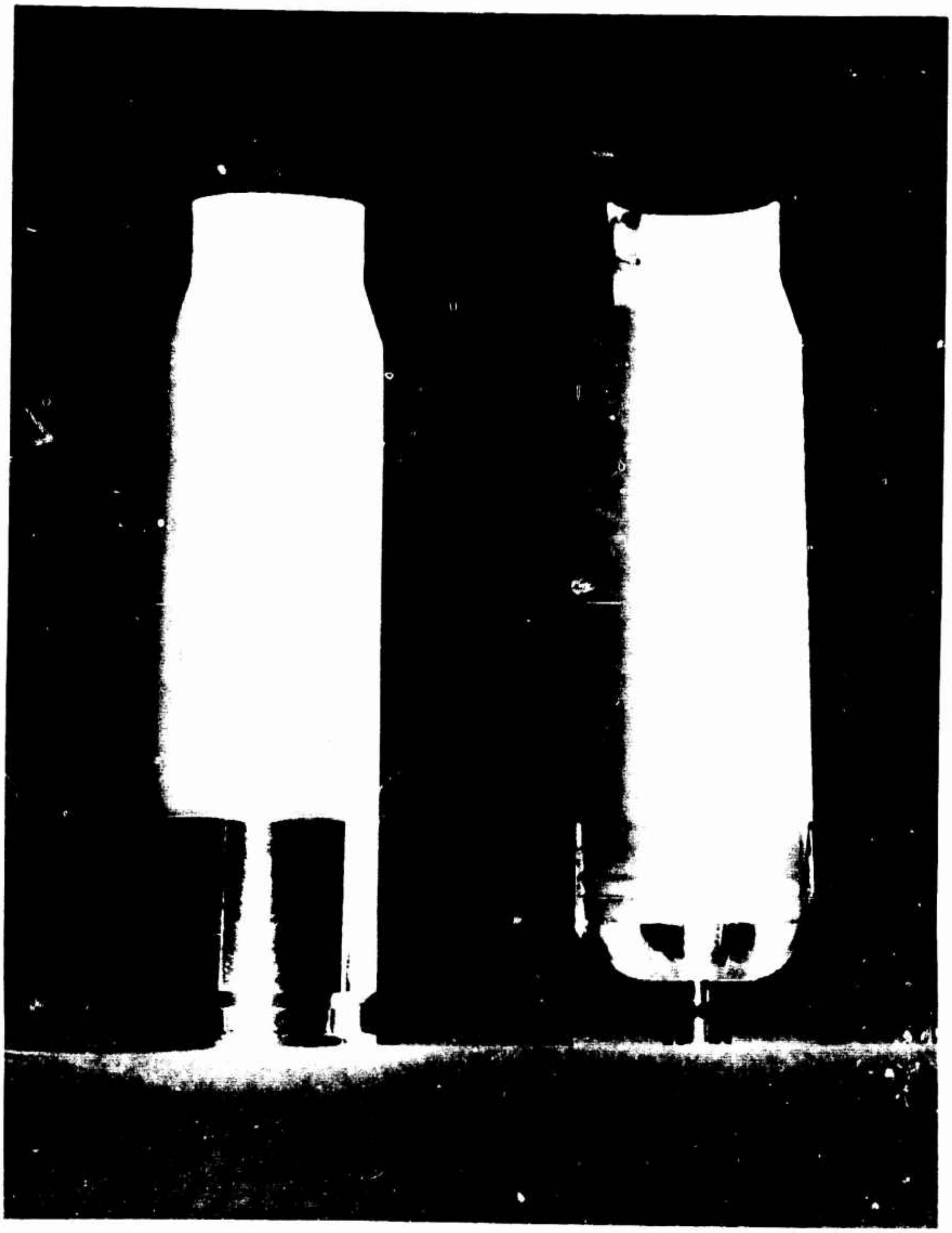


Figure 1. 20mm Plastic/Aluminum Cartridge Cases

The final design of the base contains two buttresses corresponding to those on the plastic body for mechanically locking the two components. The thin walls of the base expand outward at firing to contact the chamber. The outside dimensions are such that a line-to-line contact with the chamber will exist at the minimum chamber and maximum base size tolerances. At the opposite dimensional tolerances, maximum chamber and minimum base, a clearance of 0.004 inch on the diameter exists. The material elongation is sufficient to permit base expansion at firing to contact the chamber walls.

The base will accept the standard M52A3B1 electric primer used in the M103 brass cartridge case.

To prevent corrosion, a chemical film coating per MIL-C-5541 is recommended for the aluminum base. It is a good electrical conductor so that the operation of the electric primer will not be impaired. The chemical film coating can be dyed any color should color coding of the munition be desired.

The plastic body is an injection molded part of glass-reinforced nylon. The formulation consists of type 12 nylon resin[1] mixed with 0.25 inch long glass fibers to the amount of 50 percent by weight of the total mix. The material is marketed by Thermofil, Inc., Ypsilanti, Michigan. The base resin is obtained through Henley & Co. Inc., New York, N.Y. from Hüls of West Germany. Thermofil mixes the base resin with the desired glass loading.

The outer dimensions on the plastic body provide a line-to-line contact with the chamber at minimum chamber and maximum case tolerances and a 0.004-inch clearance on the diameter at the opposite extremes. The joint area diameter is molded 0.010 to 0.015-inch oversize to provide for a tight fit with base in order to prevent rotational slippage and to effect a watertight seal. The seal had been demonstrated to be watertight by a 72-hour immersion test.

The wall thickness is 0.062 inch forward near the necked-down area of the case. This thickness provides sufficient strength to resist the squeeze from the M14 link.

Projectile retention is accomplished with a continuous, circumferential bead that is molded into the inside surface of the case neck. The bead mates with the crimp groove in the M55A2 projectile. At assembly, the projectile is pressed into the case neck with the neck free to expand radially to allow the bead to ride over the rear of the projectile and snap into the crimp groove. At firing, with the neck supported radially by the chamber, the bead is sheared out by the projectile. A force of 800 lbs is required to shear out the bead with the neck supported radially. A detail drawing of the plastic body, AAI Drawing No. 53593-40002, is presented in Appendix I.

[1] Huls resin No. L-1801

The assembled munition contains 37.3 grams of WC 870 double base propellant manufactured by Olin Mathieson. The total available case volume is 2.44 cubic inches. The munition component weights are:

PLASTIC/ALUMINUM CASE	38.0 grams	0.0838 lb
WC 870 PROPELLANT	37.3 grams	0.0822 lb
M55A2 PROJECTILE	99.0 grams	0.2183 lb
TOTAL	174.3 grams	0.3843 lb

Figure 2 shows the assembled 20mm plastic/aluminum cartridge case munition.

b. PERFORMANCE

The charge weight of 37.3 grams of WC 870 double base propellant loaded in the 20mm plastic case provided performance comparable to the M103 case which is loaded to a charge weight of 39 to 40 grams. All tests were with the M55A2 projectile. Based upon the results of ten Mann Barrel firing tests of each, the average of the velocities and pressures which were recorded with each case are:

	VELOCITY	PEAK PRESSURE
PLASTIC/ALUMINUM	3355 fps	52,800 psi
M103 BRASS	3350 fps	51,000 psi

Presented in Figure 3 are typical examples of pressure versus time traces obtained from firing tests of the plastic/aluminum and M103 cases. It may be seen that the pressure in the plastic case rises at a slightly higher rate due to the smaller case volume and peaks approximately 0.1 millisecond before that of the M103 case. The pressure decays are very similar. M61 operation was normal with the plastic case with proper feeding, chambering, and extraction.

2. 30MM CARTRIDGE CASE

a. PHYSICAL DESCRIPTION

The 30mm cartridge case is also assembled from two separate parts: an aluminum base and a plastic body, part numbers 53593-40011 and 53593-40005, respectively. Detail prints of these parts are given in Appendix II of this report. The base, machined from 7075-T6, a high strength aluminum alloy, has a tapered counterbore with three buttress-shaped teeth forming a serrated

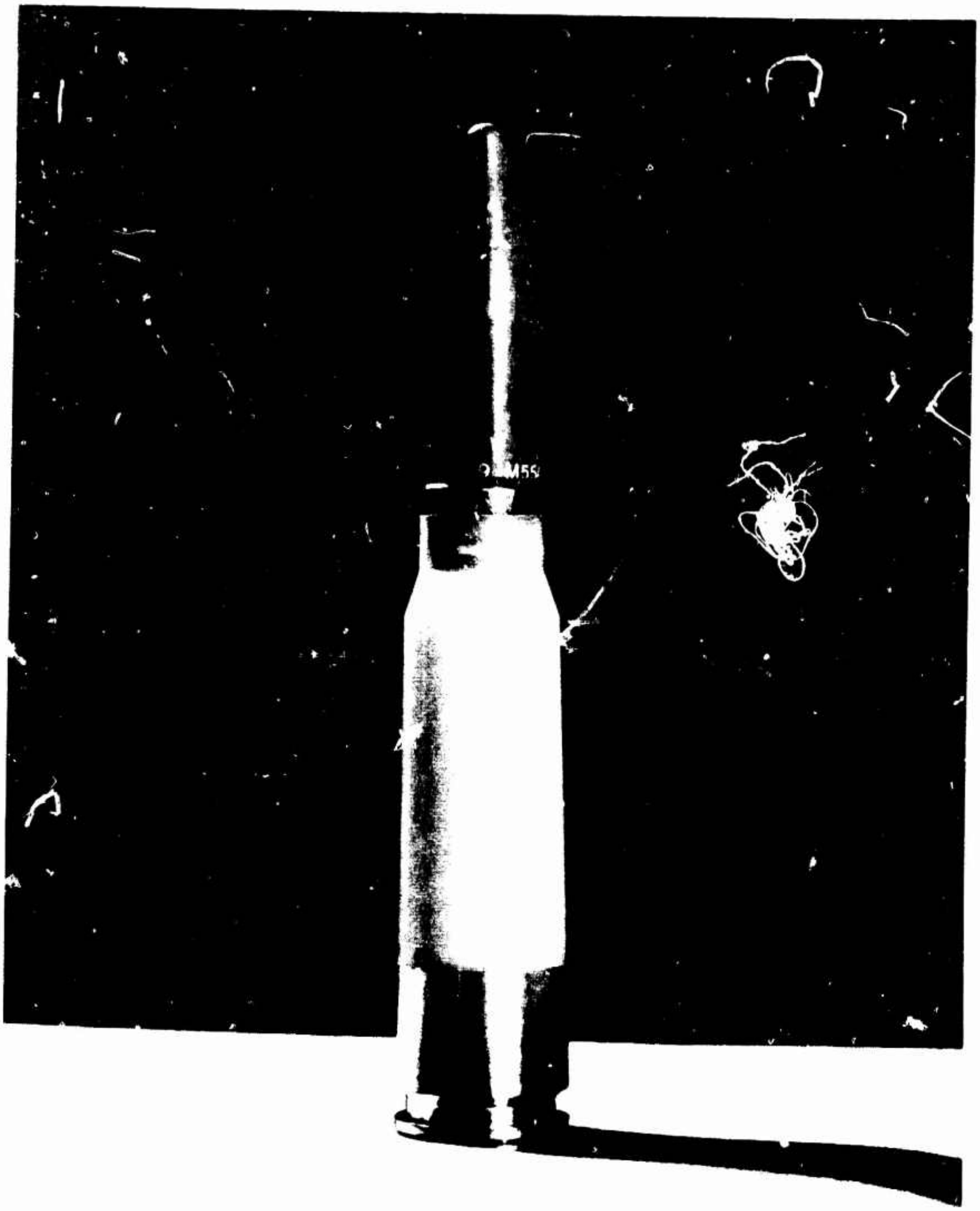
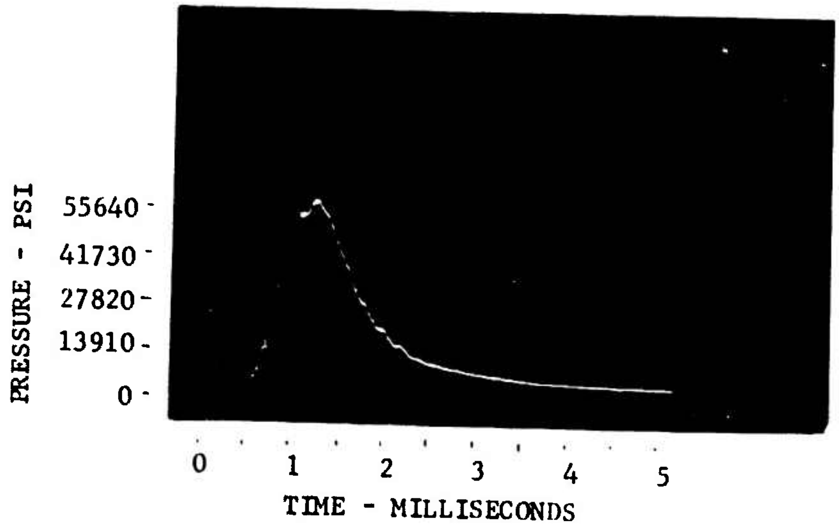
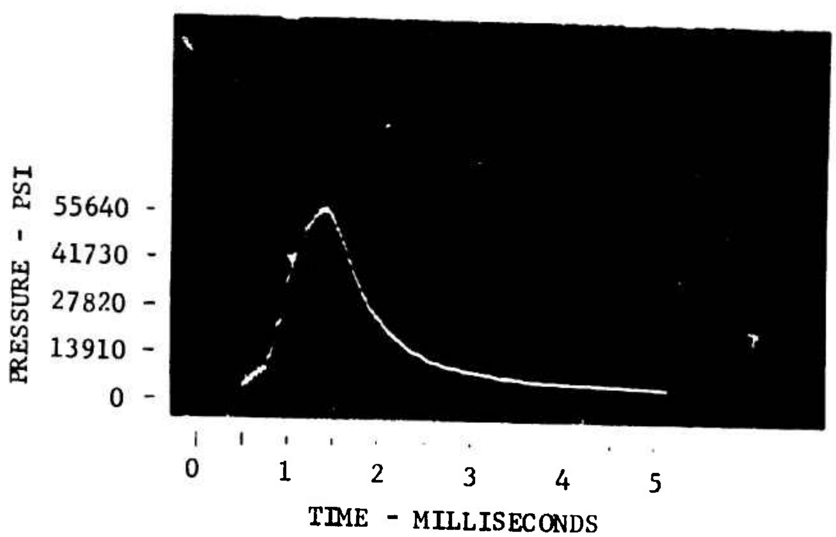


Figure 2. 20mm Plastic/Aluminum Cartridge Case Munition



PLASTIC/ALUMINUM CARTRIDGE CASE
WITH 37.3 GRAMS OF WC 870
DOUBLE BASE PROPELLANT



M103 BRASS CARTRIDGE CASE
WITH 39.5 GRAMS OF WC 870
DOUBLE BASE PROPELLANT

Figure 3. Oscilloscope Readouts of Pressure Versus Time Curve for 20mm Cartridge Cases

inside wall as shown in detail "A" of 53593-40011. The plastic body, injection molded from 43 percent glass-filled 612 nylon[2], has at its lower end a tapered outside wall with undercuts to match those of the base.

The tapered section of the plastic body has a nominal interference of 0.005 inch with the matching section of the base. When the plastic body is forced into the base, it snaps into place, forming a tightly gripped joint. The plastic body has a wall thickness of 0.096 inch and an outside mean diameter of 1.876 inches which tapers from base end to projectile end at .015 inch per inch. The diameter of the projectile end necks down in 1 inch of length to 1.301 inch diameter in order to accommodate the T328 projectile. The inside wall of this latter mentioned diameter contains an 0.010 inch high x 0.062 inch wide bead which snaps into the crimping groove of the T328 projectile when the latter is pressed into place as a final assembly operation.

The munition is percussion fired utilizing an experimental primer designated XM115 which was developed by Frankford Arsenal. Percussion firing capability was a contract requirement. The XM115 is the largest percussion-type primer available, and it was found to perform satisfactorily without a booster charge at ambient temperature. At low temperatures (-65°F), however, the XM115 would not ignite the propellant charge. For low temperature tests, a Number 111 primer with a booster charge of 0.3 gram of boron potassium nitrate was used with satisfactory results. The assembled munition contains a propellant charge of 160 grams of CIL 1379 C. The total internal case volume available for propellant is 11 cubic inches. The munition component weights are:

PLASTIC/ALUMINUM CASE	153.7 grams	0.3388 lb
CIL 1379 C PROPELLANT	160.0 grams	0.3527 lb
T328 PROJECTILE (WEIGHTED)	324.0 grams	0.7143 lb
TOTAL	637.7 grams	1.4058 lb

Figures 4 and 5 show the 30mm plastic/aluminum cartridge case and the assembled munition.

b. PERFORMANCE

Preliminary calculations showed that more than 150 grams of Canadian Industries Limited propellant CIL 1379 C were required to propel the projectile at a muzzle velocity of 3500 fps. Since the behavior of the plastic/aluminum case was unknown and despite analysis indicating a safe assembly, the first two cartridges were loaded with lower charges of 100 and 150 grams in order to ascertain their being safe. The remaining cartridges contained 160 grams of propellant.

[2] DuPont's resin Zytel 151

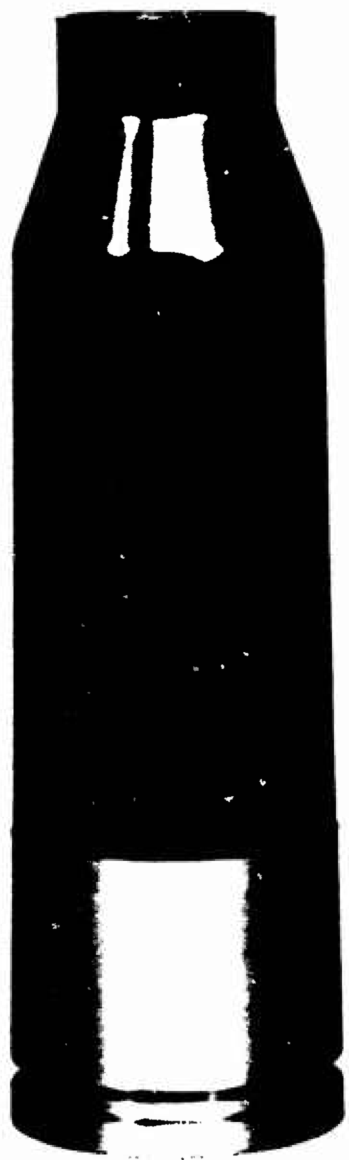


Figure 4. 30mm Plastic/Aluminum Cartridge Case

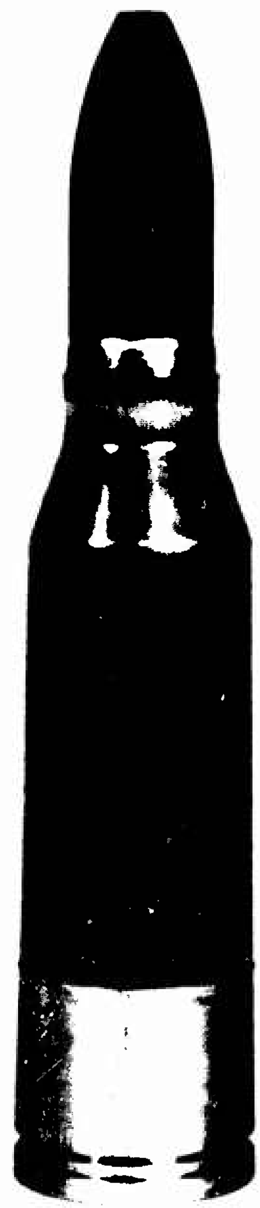
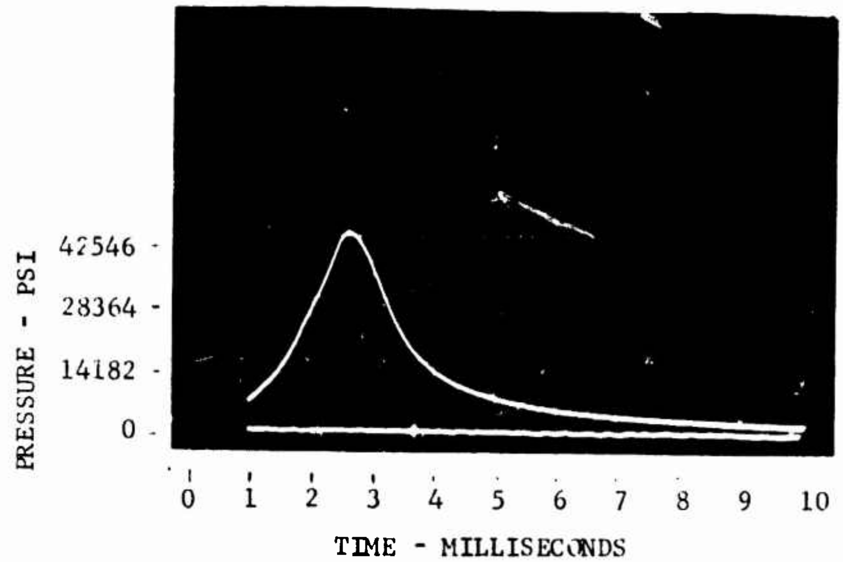


Figure 5. 30mm Plastic/Aluminum Cartridge Case Munition

The projectile used in the assembly of these rounds was taken from 30mm ammunition, TP239, supplied as GFP. The nose of the projectile was removed, lead shot was added to the body cavity until the weight of the total projectile reached 324 grams.

At the required velocity of 3500 fps, the peak pressure is approximately 42,000 psi. Figure 6 is a typical pressure versus time curve obtained from Mann barrel tests.



30MM PLASTIC/ALUMINUM CARTRIDGE CASE
WITH 160 GRAMS OF CIL 1379C
MUZZLE VELOCITY: 3497 FPS

Figure 6. Oscilloscope Readout of Pressure Versus Time Curve For 30mm Plastic/Aluminum Cartridge Case

SECTION III

TEST METHODS

1. VELOCITY MEASUREMENT

The projectile velocity was measured using counter chronographs in conjunction with light-sensitive velocity screens. The velocity screen consists of a tungsten lumi-line tube light source which shines directly across the projectile line of flight to a photoelectric tube. As the projectile passes through the screen, its shadow is cast on the photoelectric tube which then sends out an electrical pulse. The electrical pulse is used to trigger or to stop a counter chronograph. With the start and stop screens set at a known distance apart, the recorded time to travel that distance will yield the average velocity between screens. For these tests, two sets of velocity recording apparatus were used. The redundant set-up was arranged with the start and stop screen pairs 10 feet apart, with the first start screen being 20 feet from the muzzle and the second start screen 34 feet from the muzzle. The two readings were averaged.

2. PRESSURE MEASUREMENT

To obtain pressure versus time traces, a small hole was drilled in the case wall corresponding in location to a port in the Mann barrel chamber. At firing, the gas pressure acts against a piston inserted in the chamber port which, in turn, transmits the force to a quartz dynamic force transducer. The transducer sends an electrical pulse which is then read-out on an oscilloscope and subsequently recorded on a Polaroid photograph. The resulting photograph is a pressure versus time trace.

3. TEMPERATURE EXTREME TESTS

The 30mm case was tested at -65°F by packing the outside of the breech and chamber with dry ice after the round was loaded into the Mann barrel. A thermocouple attached to the projectile nose monitored the temperature. Upon reaching the desired temperature, the leads were removed and the round was fired. Figure 7 shows the 30mm barrel.

The 20mm case was tested at temperature extremes by conditioning the loaded ammunition separately for a minimum of 4 hours at the desired temperature. For cold tests (-65°F), a cold chamber operating with liquid CO_2 was utilized. For hot tests, an electrically heated chamber was used. Both environmental chambers were equipped with automatic temperature controls. When ready for firing, the rounds were transported to the test site in insulated containers, loaded in the M61 and quickly fired to minimize any temperature change. Elapsed time with the rounds in the container was about 2 minutes. Time to load the rounds from the container into the gun and fire was about 10 seconds.

Figure 7. 30mm Mann Barrel

SECTION IV

DEVELOPMENTAL TESTING

1. 20MM CARTRIDGE CASE

The basic concept for the cartridge case design had been established previously during in-house projects conducted at AAI. The general design was scaled to 20mm size using the standard M103 brass case as a model for the outside dimensions.

One of the most important considerations at the outset and throughout the effort was the choice of materials for both case components. From past experience on in-house work, aluminum was a likely choice for the base. Since the base is unsupported at the extractor groove at firing, high stress levels are experienced due to internal gas pressure. A high-strength alloy, 7075-T6, was chosen for the initial tests. This alloy was eventually incorporated into the final design after tests with other aluminum alloys proved unsuccessful and steel proved to be too heavy for any practical advantage.

In choosing a plastic for the case body for the initial testing, a thorough material search was conducted with a study of the properties of various types of plastics to find those most compatible with the design requirements of this feasibility study. Properties investigated included tensile strength, impact strength, elongation, water absorption, coefficient of thermal expansion, flammability, and effect of various acids, alkalines, and solvents. As a result, two materials stood out as having the base combination of mechanical and chemical properties. They were polyethylene and nylon with various glass loadings for added strength. Specific formulations initially molded and tested were:

POLYETHYLENE/UNFILLED	(DuPONT'S ALATHON)
POLYETHYLENE/30% GLASS	(DuPONT'S ALATHON)
66 NYLON/40% GLASS	(LNP'S RF-1008)
612 NYLON/43% GLASS	(DuPONT'S ZYTEL 77G43)

The plastic case rounds were fired in a Mann barrel with velocity recorded. The general results were that the 612 nylon/43 percent glass emerged as the best of these materials. Its combination of high impact and tensile strengths and good elongation make it compatible with the design requirements.

The glass-filled and unfilled polyethylene cases experienced circumferential failures at the joint area, and the 66 nylon/40 percent glass was too brittle to allow assembly of the projectile into the case without cracking the neck.

For the test firings, standard 20mm propellant charges were loaded into plastic cases. The resulting velocities were slightly higher than those of the standard ammunition. They averaged 3450 feet per second (approximately) while the standard 20mm delivers 3380 feet per second. The increased velocity is attributed to a combination of a slightly smaller case volume even though the plastic case accepts the full standard propellant charge and a diminished heat loss through the plastic walls as compared to that of brass. The pressure in the plastic case was also slightly higher than in the standard. Figure 8 is a comparison of the pressure versus time traces obtained in firings of a brass M103 and a plastic/aluminum case with identical charge loadings of 39.5 grams of the standard propellant WC870. The velocities and peak pressures recorded for these two tests were:

BRASS M103 CASE	3367 fps 54,600 psi
PLASTIC/ALUMINUM CASE	3401 fps 57,000 psi

During these tests, projectile retention was accomplished by two methods: (1) a bead was molded into the inside diameter of the neck and machined to the proper shape and this bead mated with a groove in the projectile (2) the projectile was retained by adhesives. Problems were encountered with both methods. With the molded bead, some neck failures occurred. Upon firing, the case neck failed in tension at the bead location indicating the bead shear strength exceeded the tensile strength of the case neck. To reduce the bead shear strength, some areas of the bead were removed making it discontinuous. This was unsuccessful as the forces were then localized and partial neck failures occurred. Excellent results were obtained with a continuous bead machined to half its original thickness. No neck failures occurred with this configuration.

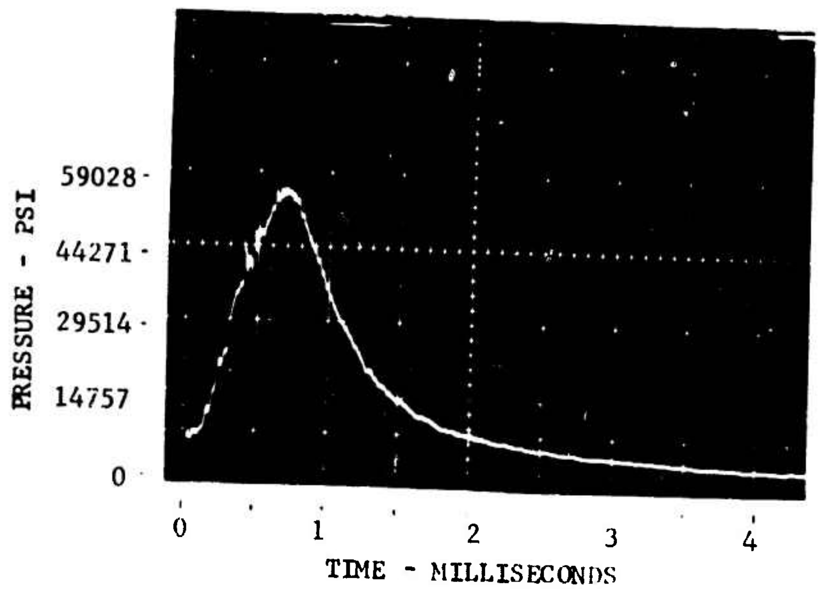
A number of epoxies were tested for projectile retention characteristics with actual test firing. The results were generally inconsistent even when the same type of epoxy is used repeatedly. Much depends on the mix ratio, surface preparation, and method of cure. The epoxies tested were:

ARMSTRONG A-31

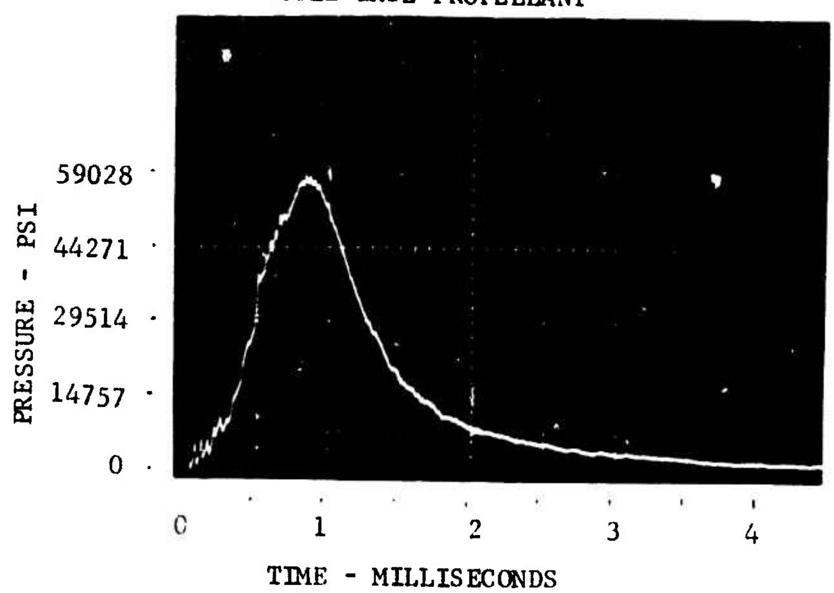
RESIWELD 7004

BIGGS R-393

SMOOTH-ON PB-1



M103 BRASS CARTRIDGE CASE
WITH 39.5 GRAMS OF WC870
DOUBLE BASE PROPELLANT



PLASTIC/ALUMINUM CARTRIDGE CASE
WITH 39.5 GRAMS OF WC870
DOUBLE BASE PROPELLANT

Figure 8. Oscilloscope Readouts of Pressure Versus Time Curve for 20mm Cartridge Cases

Because of the relatively good results with the thinner, continuous machined bead and the inconsistencies encountered with the epoxies, it was decided at this time to concentrate on perfecting a molded bead design for projectile retention. The highest bullet pull that can be achieved, 1000 lb, is governed by the tensile strength of the case neck, the size of which is set by projectile outside diameter and chamber inside diameter. The molded bead shear strength can, if the bead is heavy enough, exceed the neck strength.

Since the 612 nylon/43 percent glass gave the best results in the Mann barrel firings, a number of cases were molded for firing in the M61 gun.

In preparation for firing in the M61 cannon, the propellant charge was downloaded for the plastic/aluminum case. Through a series of Mann barrel tests, a charge weight of 38.5 grams was established as that which delivers the same performance as the standard round. This weight is approximately a gram less than the standard load.

Testing with the M61 gun was initiated with cycling tests to study the integrity of the plastic/aluminum case. Assembled rounds were linked and cycled through the weapon without being fired. These tests were successful, and preparations were made for firing tests. A single plastic case round was at first fired by manually loading it into the feeder. The round was fired and the case was ejected properly. Two rounds with plastic/aluminum cases were then linked at the end of a belt of 12 standard rounds. The plastic/aluminum cases were placed last to insure that the gun would be up to speed, thus subjecting them to the highest acceleration loads. These rounds were fired successfully. The test was repeated with 6 plastic/aluminum case rounds following 12 standard rounds; again the firing was successful.

During these M61 tests, projectile retention in the case was accomplished by a molded circumferential bead in the inside diameter of the neck which mates with the crimp groove in the 20mm projectile. For the tests described above, the bead was the same size and shape in cross-section as the projectile crimp groove. As a result, some tension failures occurred in the case neck at the bead location indicating too high a bead shear strength. All subsequent testing was performed with the continuous bead, but machined to half its original thickness, with excellent results. With this configuration, the rear half of the bead remains, contacting the rear of the projectile groove while the rotating band bottoms on the case mouth.

Testing was resumed with the modified retention bead in the cases, and no other neck failures have occurred. The final M61 test of this initial series involved the firing of a belt of 24 plastic/aluminum case rounds with the test recorded by both high speed and conventional movie cameras. All rounds fired, and all cases were extracted and ejected properly.

During testing, gun rate was measured by a microphone and oscilioscope set-up which recorded the explosive bursts in conjunction with the known oscilloscope sweep. From this, the rate was found to be 3300 rounds per minute with the M61 driven by the 24-volt battery provided as GFE. With the addition of a 12-volt battery in series with the 24-volt battery, the rate was raised to 4300 rounds per minute. Plastic/aluminum cases have been fired at both rates. Figure 9 is the resulting oscilloscope trace of the detonations of the M61 firing at 4300 rounds per minute.

With the modification of the retention bead, the only case damage occurring at firing was a small longitudinal crack 0.25 inch long just aft of the case taper. This occurred in 3 of 50 cases fired in the M61 and appeared to be caused by the squeeze of the forward part of the M14A1 link damaging or weakening the plastic locally. To correct this, the mold was modified to strengthen that area of the case by making the case wall thicker. Figure 10 illustrates the modified case with the locally strengthed wall. Material was removed from the mold core so that plastic would be added to the inside of the case wall at that area.

Upon receipt of the modified cases made of 612 nylon/43 percent glass, a series of Mann barrel tests was conducted to check velocities and pressures and to establish a charge weight prior to testing with the M61. It was found that a further reduction in charge weight was necessary to keep the pressure within acceptable limits (approximately 57,000 psi). The established charge weight was 37.3 grams of propellant taken from standard 20mm rounds. The charge weight for the unmodified plastic/aluminum case had been 38.5 grams. During the Mann barrel testing, the modified case performed well with no damage occurring to the case.

When tested in the M61, however, the modified case did not perform as well as expected. In approximately half of the plastic/aluminum cases fired in the gun, case neck failures occurred. In these failures, the neck separated from the body of the case just forward of the taper. The neck then continued out the barrel following the projectile. Gun operation was not adversely affected by these neck failures as they were not of a serious nature. It was judged, however, that this condition would be undesirable for a final case configuration.

Through further testing it was determined that the fit of the projectile in the case mouth was too tight. The outside diameter of the case was designed to produce a fit ranging from a line to line contact to a light press fit with the M61 chambers depending upon the variations of the chambers within their allowable tolerance (0.003). (It was though that this, in conjunction with the tolerance on the projectile diameter (0.004), could combine, in some instance, to provide a heavy press fit on the front of the case at chambering.) The plastic, contained, would squeeze on the projectile tightly and at firing create high frictional forces between the projectile and case. This frictional force would not be counterbalanced on the outside

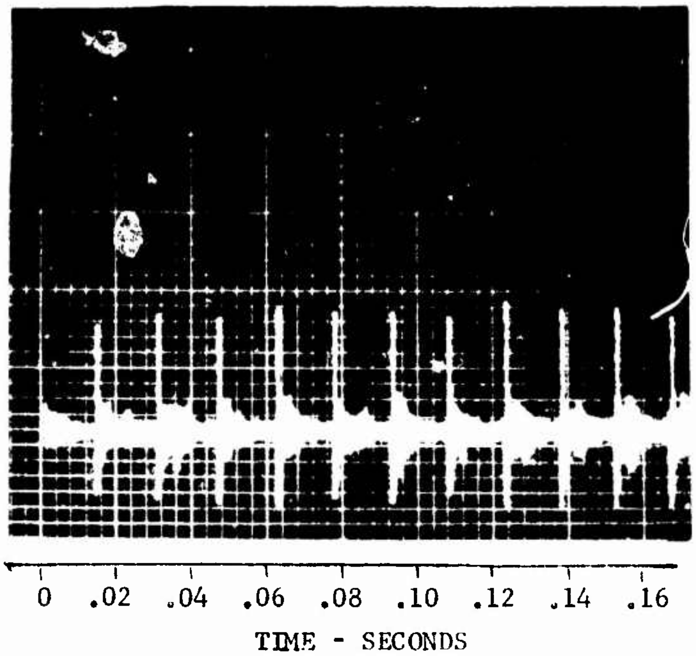
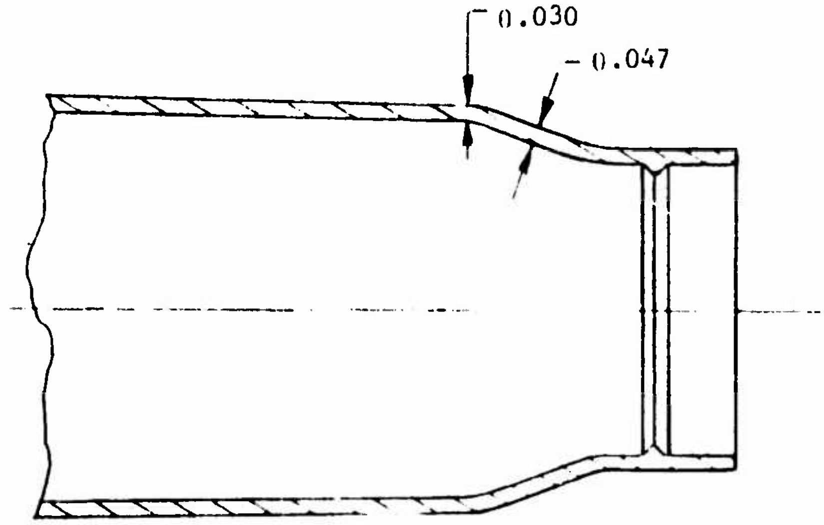
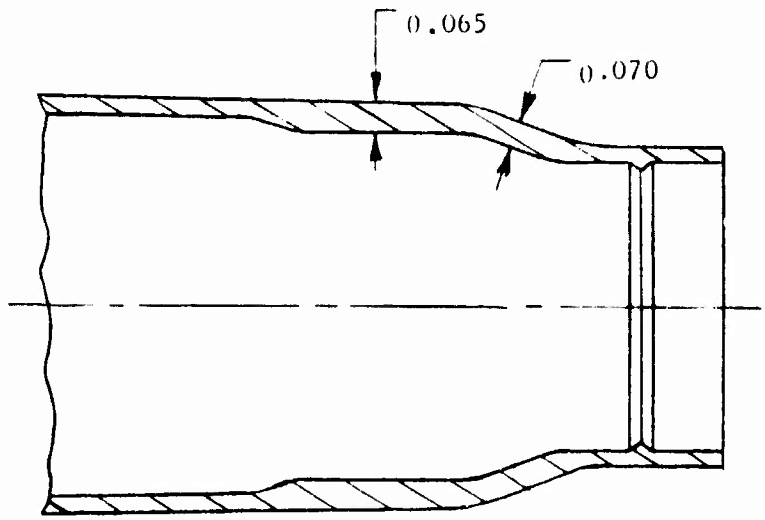


Figure 9. Oscilloscope Readout of Timing Trace for M61 Cannon Firing at 4300 Rounds Per Minute



BEFORE MODIFICATION



REINFORCED WALL

Figure 10. Case Wall Reinforcing to Resist Link Squeeze
Scale: 2/1

of the case due to the smoothness of the chamber wall. These frictional forces, in combination with the force required to shear the projectile retention bead, in some cases exceeded the tensile strength of the case and hence failures occurred. To test this theory, projectiles were machined to a rear diameter of 0.765 - 0.001 inch. (The rear diameter is normally 0.769 - 0.004 inch). For most of the projectiles, the material removed amounted to 0.003 inch on the diameter. These were fired with excellent results as no neck failures occurred. The mold was then corrected by chrome plating the core at the neck areas to 0.004 inch larger on the diameter. This produced molded cases with a slight clearance for the projectile. These cases were test fired with complete success as no neck failures or cracks of any kind occurred.

Concurrent with the investigations into the reinforced case, work continued on the unmodified thinner walled case. It was felt that the cracking problem may stem from the flow lines in the cases which run longitudinally. They are the result of a mold gating technique in which the plastic material is forced into the mold through four separate gates at the case mouth. These four flows must merge before entering the mold cavity. The result is four visible flow lines which run the length of the case, where the streams have joined. To minimize flow lines, a new core was fabricated which utilizes larger cavities beyond the gates which allow better mixing of the material before it is injected into the mold cavity itself. With this and improved molding techniques, the flow lines were minimized. (Refer to Figures 11 and 12.) The small cracks in the link area were not eliminated, however. It became apparent that the thin walled case would not withstand the link squeeze, and further testing was discontinued with this design.

The case utilizing the partially reinforced wall at the forward link contact area had been developed at this time in the effort to the point where reliable operation could be expected when fired at ambient temperatures. The next logical step would be to test it at temperature extremes. Therefore, in order to learn more of the possible problem areas which would be encountered in further developmental effort, some environmental testing at temperature extremes was initiated. Environmental testing was beyond the scope of the original contract then in effect, but it was felt that information gained would be highly beneficial.

Plastic/aluminum cases of 612 nylon/43 percent glass were test fired at the temperature extremes of 160°F and -65°F in the M61. In all tests, the rounds were conditioned at the desired temperature for a minimum of 4 hours in a separate environmental chamber and then quickly loaded and fired in the M61 so that the temperature change would be minimal.

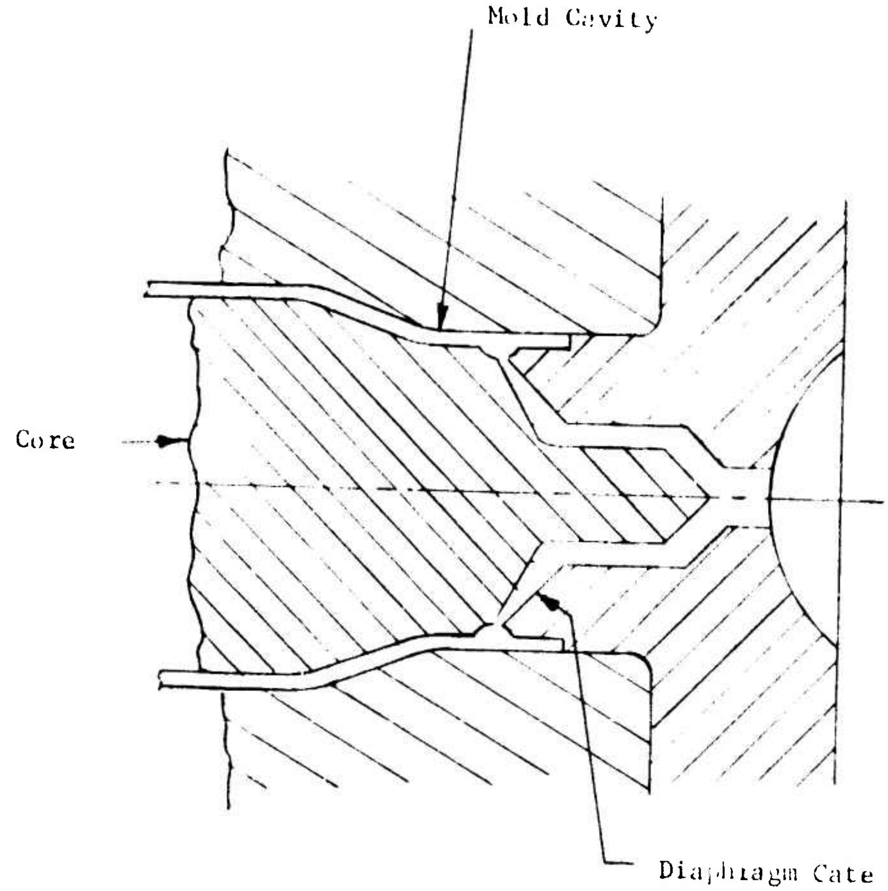


Figure 11. Mold Gating at Start of Development
Scale: 2/1

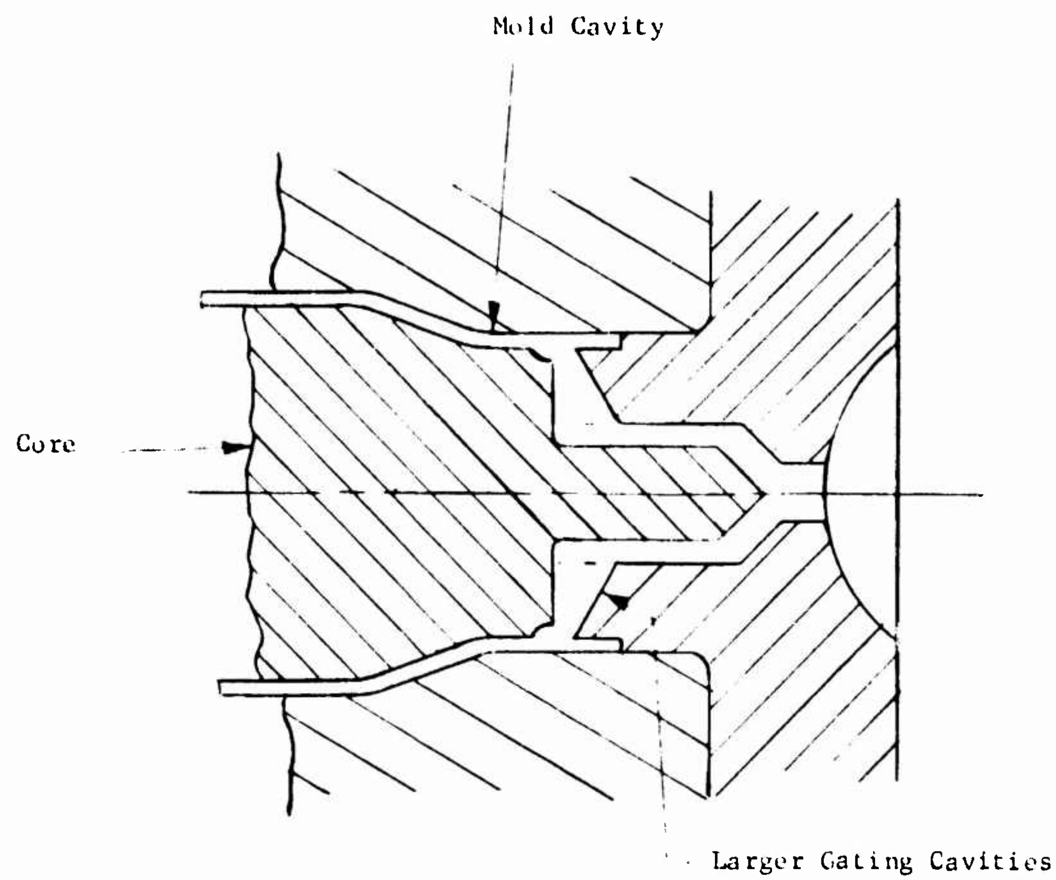


Figure 12. Improved Mold Gating
Scale: 2/1

Cases of 612 nylon/43 percent glass when tested hot yielded excellent results. Gun operation was normal, and the cases were not damaged at firing and ejection. When test fired cold, however, some problems were experienced. Approximately 30 percent of the cold firings were successful, but in the majority of cases fired, longitudinal cracks occurred in the plastic part of the case. The cracks usually ran the entire length of the plastic body, but the case itself remained intact as the plastic showed the ability to reseal itself. There was evidence of gas leakage in some of the cases at the cracks, but the leakage appeared to be minimal due to the plastic heating at the cracked area, fusing and resealing. Although the cracks in the plastic extended into the joint area surrounded by the aluminum, in most tests the aluminum was unaffected. For all environmental tests, gun operation was normal.

Some tests were conducted in which the glass content in the nylon was reduced from 43 percent to 25 percent in an effort to increase the elongation properties. Cracks still occurred, however. While the elongation properties had been improved by decreasing the glass content, the impact strength properties had been degraded and impact strength is a prime consideration for proper cold temperature operation.

Some testing at temperature extremes were conducted with cases of polycarbonate (G.E.'s Lexan 191). The polycarbonate did not crack at -65°F, but neck separations at the retention bead occurred. Polycarbonate is notch sensitive, and the machining required at the bead to achieve the proper bead thickness had created a stress concentration point. This, in conjunction with the lower tensile strength of the unfilled material, had resulted in neck tensile failures. When the polycarbonate cases were tested at 160°F, they experienced separation failures at the plastic/aluminum joint during delinking prior to chambering. With the M14 link holding the case fore and aft, the feeder in the M61 gun strips the round out of the link with a ramp that applies a side force on the middle of the case. This stresses the joint area of the case, particularly the plastic material. The lower tensile stress of the unfilled material could not withstand the side loads. Once delinked, the polycarbonate cases could be chambered, fired, and extracted normally in 160°F.

It was felt that the mechanical problems with the polycarbonate cases could be overcome with minor case configuration changed and that a workable case could be developed. One problem does exist in using polycarbonate material: its susceptibility to stress crazing after exposure to chlorinated hydrocarbons. However, polycarbonate remained in consideration as a back-up candidate material for the case in the event that the cold cracking of the nylon could not be eliminated.

At this point, cold temperature operation had been established as the most severe operating environment for the plastic material. The 612 nylon/

43 percent glass had functioned well at ambient and high temperatures, but at low temperatures most firings resulted in a longitudinal crack or a neck separation. Gas leakage at the cracks was minimal due to the plastic heating at the cracked area, fusing, and resealing itself. The neck separations often occurred when the case did not crack, and seldom did both cracking and neck separation occur on the same case. Figure 13 shows typical case failures.

To solve the neck separation problem, a study was made to check the outer case configuration for a good match with the chamber. Initially, the tapered area of the case just aft of the neck was molded with a 38° included angle. This matches the standard M103 brass case which was used as a design baseline. Drawings of the M61, however, show the chamber taper to be 39°, and measurements taken of actual M61 chamber casts reveal angles exceeding 39° and, in some instances, approaching 40°. It was felt that with a poor match at the taper, the case would not bottom properly but continue forward slightly, squeezing in and causing excessive stress at the neck. In addition, drawings of the M61 chamber indicate that there should be a 0.250-inch radius at the intersection of the two surfaces that contact the case neck and taper. Chamber casts revealed, however, this intersection to contain almost a sharp corner. With a poor match at the taper, the case would not bottom properly but would ride forward against the corner, creating a stress concentration point. This condition could lead to cold temperature neck failures and could be a factor in cold cracking.

The mold was modified to produce cases with a taper with a 39°-30' included angle. The test results were immediately improved by use of the modified cases with fewer cold temperature casualties. The overall failure rate was reduced to about 40 percent with neck separations nearly eliminated. The occasional neck separations that occurred later at cold temperatures could be attributed to an excessively tight fit by the projectile in the neck or an improperly machined retention head. The neck separations were later completely eliminated in the extended contract effort with the fabrication of a new mold core which corrected the projectile fit and molded the bead to the correct size with no other machining required.

Work continued on elimination of cold cracking with a test series to determine whether the cracks were initiated by molded-in, residual stresses. Plastic bodies made with 612 nylon/43 percent glass were annealed in Primol 355 at a temperature of 350°F for 20 minutes as recommended by DuPont representatives. Some of these were annealed after assembly into aluminum bases to relieve the additional stresses caused by the squeeze of the base on the plastic. The annealing, however, did not improve performance as cold cracking still occurred. The failure rate, in fact, increased with annealed cases.

Plastic/aluminum cases were also annealed in an oven at 200°F and at 300°F and in boiling water. Testing of these again yielded poor results.

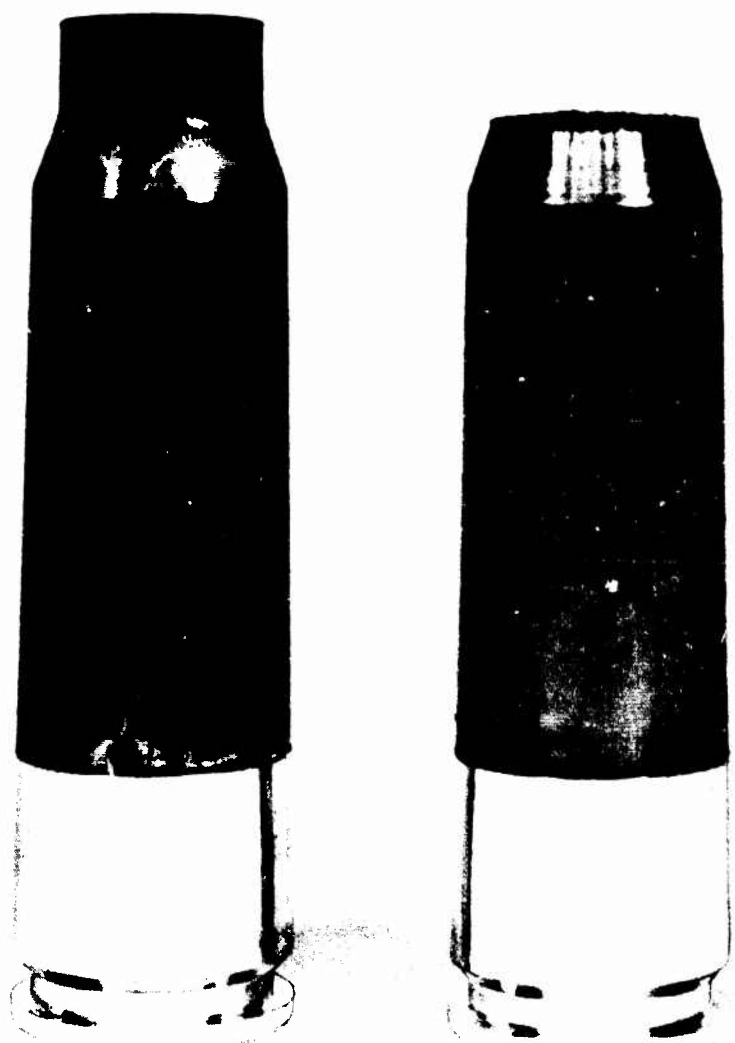


Figure 13. Typical Case Failures at Low Temperatures

In a continuing effort to eliminate the cold cracking, a number of different propellants were tested as a possible replacement for the standard propellant charge of WC870. It was felt that causes of cold temperature cracking of the 20mm case may be excessive pressure or pressure rate or a combination of both. A charge development test series was conducted to establish charge weights for a number of propellants which have a lower rate than does the standard 20mm propellant (WC870) used thus far. All are manufactured by Canadian Industries Limited. They are: CIL 1377A, 1377B, 1377C, 1379A, 1379B and 1379C. CIL 1379C was being used in the 30mm case with good results at ambient and at low temperatures. Also, the standard propellant, WC870, was tested in downloaded charges.

The charge development program was initiated using brass M103 cases and firing in a Mann barrel and recording pressure and velocity. The object was to find a propellant that delivers the same velocity but with a flatter pressure-time curve, lower burning rate, or lower peak pressure.

Table I lists the results of the firings of the CIL propellants in brass M103 cases:

TABLE I. RESULTS OF FIRINGS OF CIL PROPELLANTS IN BRASS M103 CASES

Propellant	Charge Weight (grams)	Velocity (ft/sec)	Peak Pressure (psi)
CIL 1377A	36	3322	50,320
	39	3571	59,800
CIL 1377B	37	3247	46,240
	39	3311	46,240
CIL 1377C	39	2985	34,000
CIL 1379A	38	3145	43,500
	40	3257	47,600
CIL 1379B	40	3067	39,400
CIL 1379C	35	2170	19,000
	40	2650	25,800

In all cases, there was a decrease in velocity. The CIL 1379C was eliminated because of poor velocity. The CIL 1379A, CIL 1377A and CIL 1377B were judged to have too high a peak pressure for the corresponding velocity loss. The CIL 1377C and CIL 1379B were chosen for further testing in the plastic/aluminum case since their low peak pressures might provide an acceptable trade-off for the slight loss in velocity.

Prior to testing in the M61, a test series was conducted using CIL 1377C, CIL 1379B and WC870 in plastic cases fired in a Mann barrel. The results are listed below.

PROPELLANT	CHARGE WEIGHT (grams)	VELOCITY (ft/sec)	PEAK PRESSURE (psi)	NO. OF TESTS
CIL 1377C	37	2987	38,340	Avg. of 5 Tests
CIL 1379B	37	2933	35,300	1 Test
WC870	35	3111	39,800	Avg. of 5 Tests

Although the velocities were lower than desired, it was felt that with the lower peak pressure, if the cold failure rate might be minimized, the velocity loss would be tolerable.

The charges were tested at -65°F in cases of 612 nylon/43 percent glass fired in the M61 gun. All cases using CIL 1379B failed. Those using WC870 at 35 grams and CIL 1377C showed some decrease in failure rate, but the cold failures were not eliminated. The failure rate had been 40 percent with the regular charge of 37.3 grams of WC870. With the propellant charges of 35 grams of WC870 or 37 grams of CIL 1377C, the failure rate could be reduced to 15 percent.

It was decided to discontinue testing with propellants other than the standard WC870 since the cold failures had not been eliminated by this approach. Although the failure rate had been reduced, the projectile velocity had been degraded. This was not considered to be a desirable trade-off. The propellant investigation had involved the test firing of 21 brass M103 cases and 24 plastic/aluminum cases in a Mann barrel and 79 plastic/aluminum cases in the M61 gun at -65°F, for a total of 124 firings.

Concurrent with the propellant investigation, a study was conducted on the ability to seal the assembled plastic/aluminum case munition against moisture. This involved the testing of sealants for application to the body/base joint and to the neck/projectile interface. The sealants tested were:

General Electric	RTV 154	Gray	(Silicone Rubber)
General Electric	RTV 103	Red	(Silicone Rubber)
Dow Corning	RTV 733		(Silicone Rubber)
Biggs	R-313		(Epoxy)
Biggs	R-393		(Epoxy)
Thiokol	LP-2		(Polysulfide Rubber)

Each sealant was tested for sealing properties at both the case joint and the neck-in-water immersion tests. Generally stated, the testing was successful as all sealants effected watertight seals at the joint and neck. In addition, one case was assembled with no sealant at the case joint, and it was found to be perfectly watertight.

The first portion of the testing involved immersion of the sealed area of partially assembled rounds to check visually for leakage. For this, 7 cases were assembled, 6 with sealants at the case joints and staking lacquer at the primers and 1 with no sealant or staking lacquer. The cases were placed in water, and they floated base downward with the top of the base approximately 1 inch below the surface. They were left in the water for 72 hours with the result that all case joints were watertight including the one with no sealant.

The sealants were tested at the neck of the case by assembling a projectile into only the plastic body of the case with sealant and immersing the assembly nose downward with the neck 2-1/2 inches below the surface. The samples were left for 72-hours and again all seals were watertight.

The second portion of the testing consisted of immersion of assembled rounds in water and later firing the rounds. For this, the same cases that had been used in the case joint sealant tests were utilized. They were loaded and assembled with sealant at the case neck/projectile interface and immersed in water to a depth of 4 inches for 48 hours. In this instance only RTV's were used at the neck due to their easy application. Table II lists the types of sealants used and their point of application.

TABLE II. TYPES OF SEALANTS AND POINTS OF APPLICATION

Round No.	Sealant Case Joint	Case Neck	Staking Lacquer Primer
1	RTV 154	RTV 154	Yes
2	RTV 733	RTV 733	Yes
3	RTV 106	RTV 106	Yes
4	R-313	RTV 733	Yes
5	R-393	RTV 106	Yes
6	LP-2	RTV 733	Yes
7	None	RTV 154	No

After the soak, the rounds were fired in a Mann barrel. Velocity measurements indicated that the performance was normal for all the rounds.

From these tests it is concluded that the sealing of the case joint and neck will present no particular problem. Because of its configuration the case joint is easily adaptable to sealants and is, in fact, a natural seal.

Concurrent with investigations into the use of sealants, work had continued on the cold cracking problem with the testing of additional materials. They were LNP's 612 Nylon/45 percent glass and Fiberfil's 610 Nylon/40 percent glass. Neither was successful.

The use of a new plastic material was investigated for possible application in the 20mm plastic/aluminum case design. The new thermoplastic material, Polyarylsulfone, produced by the 3M Company, is a temperature-resistant material and exhibits good properties for this application especially in the low temperature (-65°F) area. This material, however, was found to require molding pressures in the 40,000 to 50,000 psi range, which is not achieveable in AAI's plastic molding facility. Arrangements would have to be made to test mold the material at a subcontractor with facilities to mold at the high pressures. In addition, the use of this material would also require extensive modification to the existing case mold. The mold would have to be heated to 450°F electrically instead of using the existing water heating methods. Heating elements, controls, and associated hardware necessary for the modification were investigated and selected for possible procurement. A serious drawback to the use of this material was its price of approximately $25/lb in small quantities. In larger quantities, the projected price was still prohibitive.

With all the factors taken into account, it was utlimately decided that the molding of the case from Polyarylsulfone would not be done. It was reasoned that the high raw material cost would place the plastic/aluminum case in an unfavorable price situation. In addition, the extensive mold modifications required to mold this material would ruin the mold for other less expensive materials.

At this point, the original contract end date had been reached. Basic feasibility of the 20mm plastic/aluminum cartridge case had been proven with successful operation of the case in the M61 at ambient temperatures. Extra work had been performed by testing at temperature extremes and cold firing (-65°F) had been isolated as the most severe operating environment affecting plastic/aluminum cases. The failure rate at cold temperatures had been reduced from 60 percent during the initial tests to 40 percent with the standard WC870 charge and to 15 percent with lower charge weights. A total of 568 plastic/aluminum case rounds had been tested, 123 in the Mann barrel and 445 in the M61. The best material for the plastic body was 612 nylon/43 percent glass (DuPont's Zytel 77G43) and 7075-T6 aluminum for the base.

The cold cracking that had occurred did not appear to affect performance or gun operation in most instances. The plastic tended to refuze at the cracked area. With approximately 5 percent of those that cracked, however, more severe erosion of the base occurred resulting in a base burn through at the extractor groove. From visual inspection of the failures, it appeared that the aluminum base had cracked longitudinally on the side allowing the propellant gases to escape and subsequently erode the base. Figure 14 shows base erosion failure.

One problem area noted during testing and the possible source of case failures is the slanted bolt face of each bolt in the M61 gun. The bolt face has a slant of 0°-45' from the plane normal to the axis of the barrel. At firing, the base deforms to contact the full face. The deflection introduces added stresses into the base as well as the plastic body. At ambient and high temperatures, this is of no consequence but at low temperatures, it can contribute to failures since at low temperatures, the material properties of elongation and impact strength are degraded.

START OF WORK ON EXTENDED CONTRACT

With the receipt of additional funding and an extension of the contract end date, work was resumed in the development of the 20mm plastic/aluminum cartridge case. The general design of the base/case joint was investigated and modified. To facilitate manufacturing operations, the number of buttresses in the joint was reduced to two with the elimination of the forward tooth.

A particularly important change to the aluminum base was one of increasing the outside diameter to produce a closer fit with the chamber. Previously, a clearance of 0.004 to 0.010 inch on the diameter had existed between base and chamber. At firing, with the base set back against the slanted bolt face, the clearance allowed the base to cock slightly, imposing added stresses on the plastic body at the joint, possibly initiating the cold cracking. In addition, the base had to expand at firing by the amount of the clearance to contact the chamber. At -65°F under shock loading, this may have been an excessive amount of expansion. It is theorized that occasionally (2 percent of the firings) the base did crack due to the cocking and excessive expansion, and a subsequent gas erosion and burn-through at the extractor groove resulted. The base diameter was increased to achieve a fit with the chamber ranging from a 0.001 inch press to a 0.003 inch clearance on the diameter. This minimized the cocking of the base with all deformation due to the slanted bolt face occurring in the rear of the base. In this way, no additional loads were imposed on the plastic body.

It is important to note that this modification completely eliminated base burn-throughs and significantly reduced the incidence of cold cracking of the plastic body from 40 percent to approximately 10 percent.

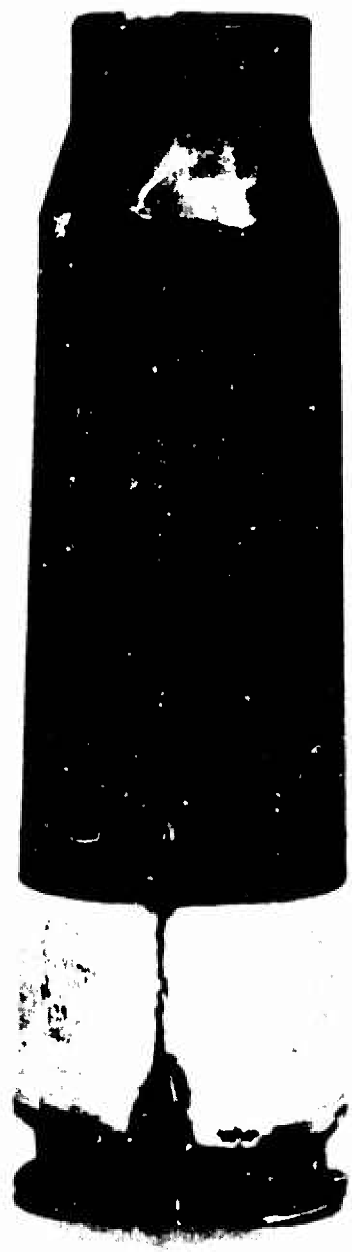


Figure 14. Base Erosion Failure on 20mm Plastic/Aluminum Case

With the start of work on the modified contract, the 20mm mold was improved. The changes to the mold we[illegible]ade in three main areas. The first involved the fabrication of a new cor[illegible]d gate suggested by the AFATL project engineer to achieve better glass dispersion within the molded part. The second change was the eliminati[illegible] of the forward base locking buttress which was judged to be unnecessary for the retention of the cartridge base. Also, the first buttress had been a source of an occasional small circumferential crack in the aluminum base. Thus, the case/base joint design now has 2 locking buttresses instead of 3. Finally, the third modification involved the molding in place of the projectile retention bead, suggested by AFATL project engineer, with the proper configuration. This eliminates the bead machining operation so that the only machining required after molding is to cut the case to the proper length. With the molding of the retention bead to the proper size, the problem of neck separations at low temperatures was eliminated. Figures 15 and 16 illustrate the modifications.

With the resumption of testing, a number of new materials were molded in addition to the 612 nylon/43 percent glass. They were:

- EASTMAN'S TENITE POLYTEREPHTHALATE (PTMT) UNFILLED
- EASTMAN'S TENITE POLYTEREPHTHALATE (PTMT)/20 PERCENT GLASS
- HÜLS'S TYPE 12 NYLON/30 PERCENT GLASS
- CELANESE'S X917 THERMOPLASTIC RESIN/30 PERCENT GLASS

The results when fired at -65°F were:

- PTMT/UNFILLED (6 ROUNDS) - ALL 6 CASES CRACKED AT FIRING
- PTMT/20 PERCENT GLASS (6 ROUNDS) - ALL 6 CASES CRACKED AT FIRING
- TYPE 12 NYLON/30 PERCENT GLASS (6 ROUNDS)

With this material, 5 of the 6 cases were broken in the feeder during delinking. This appeared to be due to a high friction between the case and link which caused excessive forces at delinking. The 1 round that passed through the feeder intact was fired with no case damage.

- X917/30 PERCENT GLASS

Cases could not be assembled without cracking the case necks, which indicated extreme brittleness.

It should be noted that in using materials that are not glass filled, such as PTMT, the resulting molded case is considerably undersize. The undersize condition may have contributed to the case failures. A problem exists

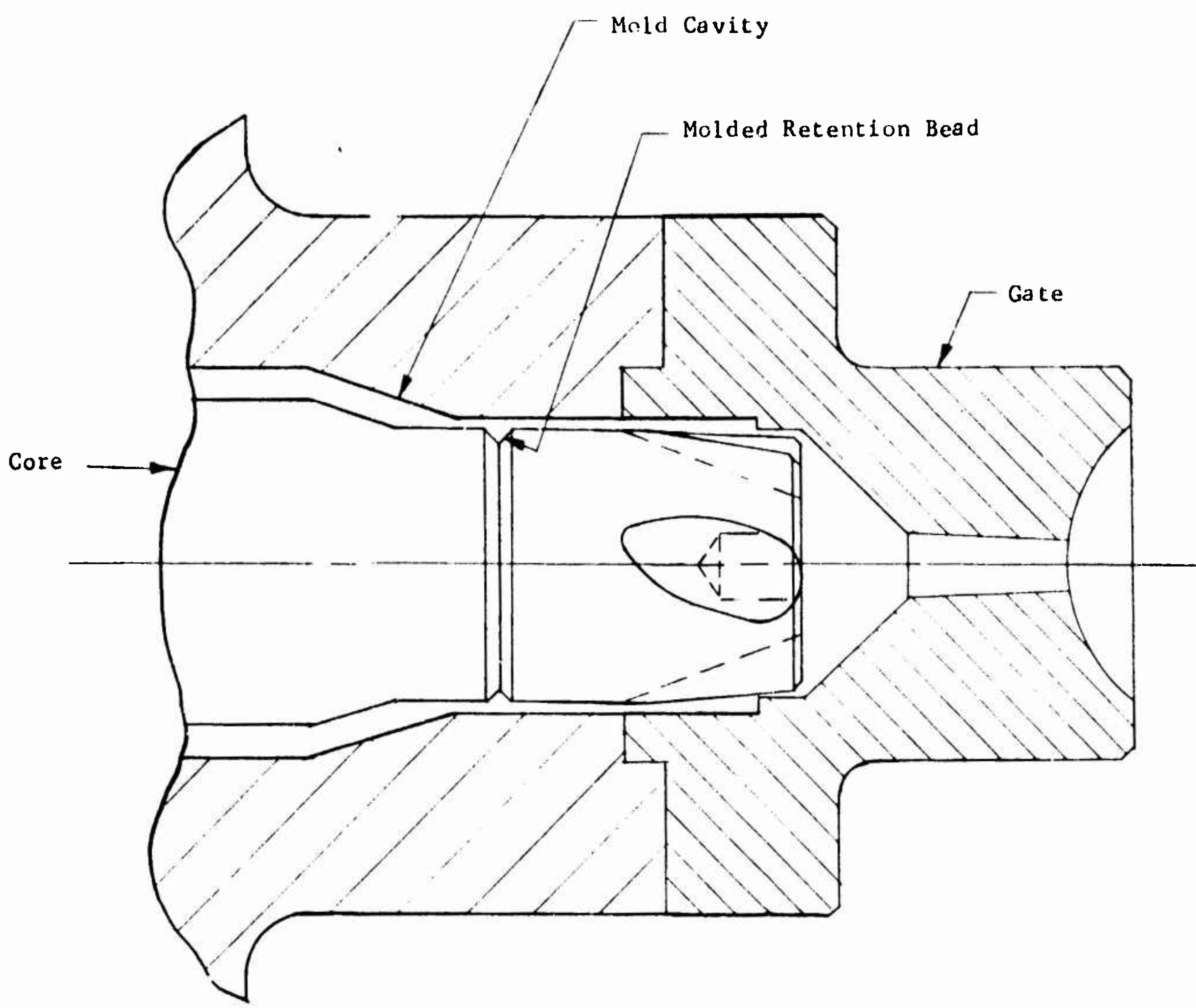
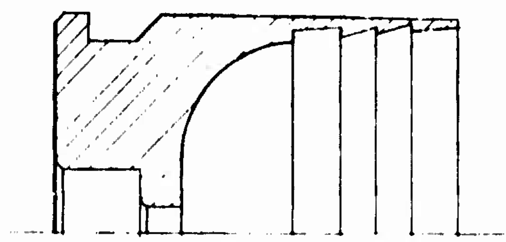
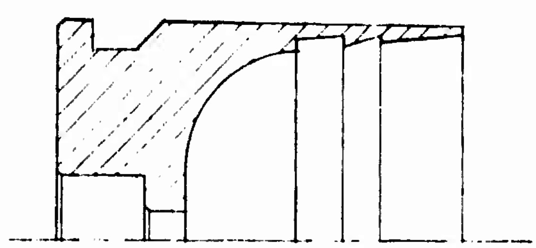


Figure 15. Mold Changes at Start of Modified Contract



Three Buttresses



Two Buttresses

Figure 16. Locking Buttress Modification

in that the same mold which has been designed for the lower shrinkages of glass filled materials is also used in molding unfilled plastics with their higher shrinkages. It becomes difficult to fairly evaluate the unfilled materials. It is felt, however, that in this instance, because of the severity of the cracks, the unfilled PTMT would not perform satisfactorily regardless of the case size.

In addition to the regular cartridge base material, 7075-T6 aluminum alloy, other materials were tested and evaluated. They were 2024-T4 and 6061-T6 aluminum alloys and steel. All bases fabricated henceforth reflected the increased outside diameter to achieve a better chamber fit discussed earlier.

2024-T4 BASES

General results are that the slightly larger diameter base which provides a close chamber fit is the better configuration since it prevents cocking in the chamber due to the slanted bolt face. Also, it was felt that the use of the softer 2024-T4 aluminum instead of the 7075-T6 might have merit since it will deform easier, at firing, on the slanted bolt face and not transmit as high a force to the plastic portion of the case. Testing at $-65^{\circ}F$ with 2024-T4 did provide good results, but at $160^{\circ}F$ the material was severely deformed with some small circumferential splits occurring. The material did not have the tensile strength to withstand the high stress levels when fired at elevated temperatures.

6061-T6 BASES

Cases with bases of 6061-T6 were test fired at ambient temperatures and $-65^{\circ}F$. The results at ambient were satisfactory but those at $-65^{\circ}F$ were not. Although 30 percent functioned properly, the remainder cracked at firing or were broken in the feeder at delinking. The feeding problem appeared to be caused by high friction between the 6061 base and link which transmitted excessive stresses to the plastic at delinking.

The other standard aluminum alloys are lower in tensile strength and therefore were not tested. Based on these tests, 7075-T6 appears to be the best of the various aluminum alloy grades for application in this area.

STEEL BASES

The use of steel bases was thoroughly investigated and found to be feasible. The primary advantage with steel is that it will not burn under the influence of high pressures and temperatures as aluminum does so that there is no possibility of a burn-through.

Cases with steel bases were fired in the Mann barrel and M61 to determine the best configuration for the steel base. Steel bases identical to the aluminum base configuration were fired successfully at ambient temperature. Effort was made to make the base as light as possible by designing thinner walls and utilizing the proper heat treatment. It was attempted to develop a steel base that would ultimately compare favorably with the aluminum base in both weight and performance. Heat treated 4340 steel bases were designed to reduce the weight as much as possible yet still withstand the firing pressures. Twenty-one firings were conducted in which various combinations of base thickness, height, and heat treatment were tried to produce a minimum weight case. The resulting plastic/steel case which was fired successfully in the M61 after being tested in the Mann barrel weighed 46 grams as compared to 34 grams for the plastic/aluminum case and 120 grams for the M103 brass case.

With the apparent elimination of the aluminum base burn-throughs and consideration of the weight increase using steel bases, it was ultimately decided that 7075-T6 aluminum would be the better choice of materials for the cartridge base. With the establishment of the final configuration and material for the base, all effort was then concentrated on the problem of cold cracking of the plastic body.

Testing continued with the evaluation of new materials and improved versions of those already tried as these became available.

POLYCARBONATE/4 PERCENT AND 8 PERCENT GLASS (G.E.'S LEXAN 141)

Prior tests had been made with unfilled and 20 percent glass-reinforced Lexan. The results of these tests were that the unfilled material worked at -65°F but was not strong enough at +160°F, and the glass-filled material was too brittle even under ambient conditions. Tests were conducted at -65°F with 4 percent and 8 percent filled material in an effort to strengthen the unfilled material without making it too brittle. Both materials were successful in a limited number of tests at the cold conditions. High temperature firings, however, were unsuccessful as tensile failures occurred.

POLYCARBONATE/10 PERCENT GLASS (G.E.'S LEXAN 500)

Lexan 500/10 percent glass showed some promise as 12 rounds were fired at -65°F with no failures of any kind. Six were then fired hot at 160°F, and 5 of the 6 cases separated at the joint probably because of high friction between the Lexan and chamber and lower material strength at the joint area. Testing with polycarbonate was discontinued.

POLYESTER/30 PERCENT GLASS (G.E.'S VALOX 420)

The thermoplastic polyester, G.E.'s Valox 420 which contains 30 percent glass, was molded and test fired in the M61 at -65°F. The results were not satisfactory as all cases failed. Valox 420 apparently is not suited for the high stresses encountered in case operation.

ETFE FLUOROPOLYMER/UNFILLED AND 25 PERCENT GLASS (DUPONT'S TEFZEL)

Cases of filled and unfilled Tefzel were molded for testing with DuPont technical personnel present to assist in establishing proper molding parameters. One immediately apparent problem was the large amount of shrinkage in the molded part resulting in undersized cases.

Firing of the cases at -65°F yielded a failure rate of 15 percent mainly due to the cases being undersize. It was felt that, with a mold tailored to the requirements of Tefzel, a satisfactory case could be produced. The price of Tefzel, however, appears to be prohibitive. Presently the cost is $9 per pound; and the projected price in quantity will be $6.50 per pound at the very minimum. This will not be competitive when compared to the current price of DuPont 612 nylon/50 percent glass, which is $2.00. No further work was performed with Tefzel.

612 NYLON (MODIFIED)/43 PERCENT GLASS (DUPONT'S FE 5024)

The special formulation of glass-filled nylon with added tougheners designated FE 5024 was formulated by DuPont, molded, and test fired at -65°F. The results of the tests were unsatisfactory in that the failure rate was 67 percent. DuPont was notified of this and agreed to try another approach toward a solution, which has to increase the glass content of the material. Since considerable improvement in the failure rate was achieved as additional glass was added up to 43 percent, the maximum available at that time, it was agreed to try 50 percent glass. This material was then formulated by DuPont.

612 NYLON/50 PERCENT GLASS (DUPONT'S FE 5030)

The initial tests with 612 nylon/50 percent glass were highly successful. Thirty firings were conducted, 20 at -65°F, and 10 at 160°F with no failures of any kind. This was the best performance to date of any material.

TYPE 12 NYLON/30 PERCENT GLASS LONG FIBERS (HÜLS'S)

Hüls had prepared a type 12 nylon with 0.25 inch long fibers instead of their standard 0.125 inch fibers. The initial firings at -65°F with this material were moderately successful in that, of 25 firings, only 2 failures occurred. When fired hot, however, tensile failures occurred at the transition point between the heavier, reinforced section and the thinner wall aft. The tensile failures were attributed to the lower tensile strength of the material at elevated temperatures. The type 12 nylon did show promise with the successful cold tests, and the addition of more glass would help performance, both hot and cold.

At this time, two materials emerged as the prime candidates for application in the 20mm plastic/aluminum case design. They were 612 nylon/50 percent glass and type 12 nylon with a slight edge given to the 612 nylon because of its higher glass content.

It was decided to test larger quantities of rounds to better establish the integrity of cases using 612 nylon/50 percent glass. The initial tests consisted of 20 firings in the Mann barrel under the ambient conditions to compare performance with the standard brass ammunition. The charge was established at 37.5 grams of WC870 propellant which is 0.2 gram more than previously used on the successful firings. Comparison of the performance of the two rounds is:

	AVERAGE PEAK PRESSURE	AVERAGE VELOCITY
M103	50,765	3349
PLASTIC/ALUMINUM	48,138 [3]	3346

Using this propellant charge, 54 cases were fired in the M61 after being conditioned at -65°F for four hours. Eleven cases, or approximately 20 percent, cracked. An immediate investigation was conducted to determine the reason for these failures since previous tests of this material had produced 20 firings with no failures occurring under the cold conditions. To determine the impact of the increased charge, twelve cases were fired with 37.3 grams of propellant at -65°F and four cracked. This indicated that the increased charge was not the cause of the failures. It was then obvious that the increased failure rate was due to loss of properties in the plastic component, and DuPont was contacted to evaluate the situation. Two possible problem areas were recommended for investigation, both of which could cause a loss of properties in the molded parts: (1) DuPont suggested raising the melt temperature to 560°F instead of 510°F as had previously been used. New cases were molded, and twelve were fired at -65°F with only one failure which is a significant improvement; (2) DuPont also suggested that excessive moisture in the plastic raw material prior to molding could have caused a loss in the physical properties. Even though the material was dried prior to molding, the moisture content could still be greater than as supplied. DuPont then supplied a new lot of material to determine the effect of the moisture content.

Additional tests were conducted with the new batch of DuPont's 50 percent glass-filled 612 nylon which was molded immediately after opening the sealed container. The moisture content was checked and found to be .024 percent, an exceptionally low amount. These cases were molded at the higher melt temperature. Fifty cases were fired at -65°F and 8 cracked.

Theorizing that high case friction might cause excessive stresses in the plastic body, some cases were Teflon-coated to evaluate this concept. The 612 nylon/50 percent glass cases were sprayed with DuPont's Teflon Resin No. 850-204, air dried, and then flame-fuzed prior to assembly. It was anticipated that the Teflon coating would provide decreased friction when delinking,

[3] Due to subsequent mold changes which reduced the internal case volume, the peak pressure in the final case configuration 53,000 psi as stated earlier.

feeding, and extracting and would also provide a sealed external surface on the nylon. Upon testing the coated cases at -65°F, the failure rate had been reduced to 7 percent but the cracks had not been eliminated.

Another type of coating on the 612 nylon/50 percent glass case was tried. Xylon, made by Whitford Corporation, has better adhesion and lower curing temperature than does Teflon. Testing, however, yielded poor results with a failure rate of 30 percent. Some of the failures were tensile failures indicating an increase in friction.

The use of coatings on the nylon case was generally undesirable. Teflon does not adhere well since the proper curing temperature cannot be achieved without adversely affecting the nylon. The Xylon coating increased the coefficient of friction rather than decreasing it. The molded nylon case normally has a low coefficient of friction (on the order of .1) and is difficult to improve upon. Any further evaluations of coatings for the plastic body were discontinued.

MOLD CHANGES

At the request of the government program manager, a mold change was made to the core to eliminate the sharp transition between the thick and thin sections of the case at the forward, reinforced area. This area could contain residual stresses resulting at molding and cooling at different rates because of the differences in thickness. The thin section was definitely a weak point in tension as evidenced by the tensile failures at high temperatures with the type 12 nylon/30 percent glass cases. Figure 17 illustrates the change.

An improved formulation of type 12 nylon with increased glass loading up to 50 percent was received at this time. The type 12 nylon/30 percent glass had achieved moderate success at low temperature, but tensile failures occurred at high temperatures. The 50 percent glass loading would make it competitive with the 612 nylon/50 percent glass.

With the core modification completed, cases of 612 nylon/50 percent glass and type 12 nylon/50 percent glass were fabricated for testing. A thorough dimensional inspection of the assembled cases were conducted prior to firing at -65°F to determine if those that fail are dimensionally different from the others. Figure 16 is an illustration of the pertinent dimensions that were checked.

Firing of the cases at -65°F produced failure rates of 33 percent for the 612 nylon and 8 percent for the type 12 nylon. The inspection record was then compared with the test results. In general, the results indicated that the cracks occurred when the "B" dimension (refer to Figure 18) was on the low side of the average. Based on this reasoning, the mold was again

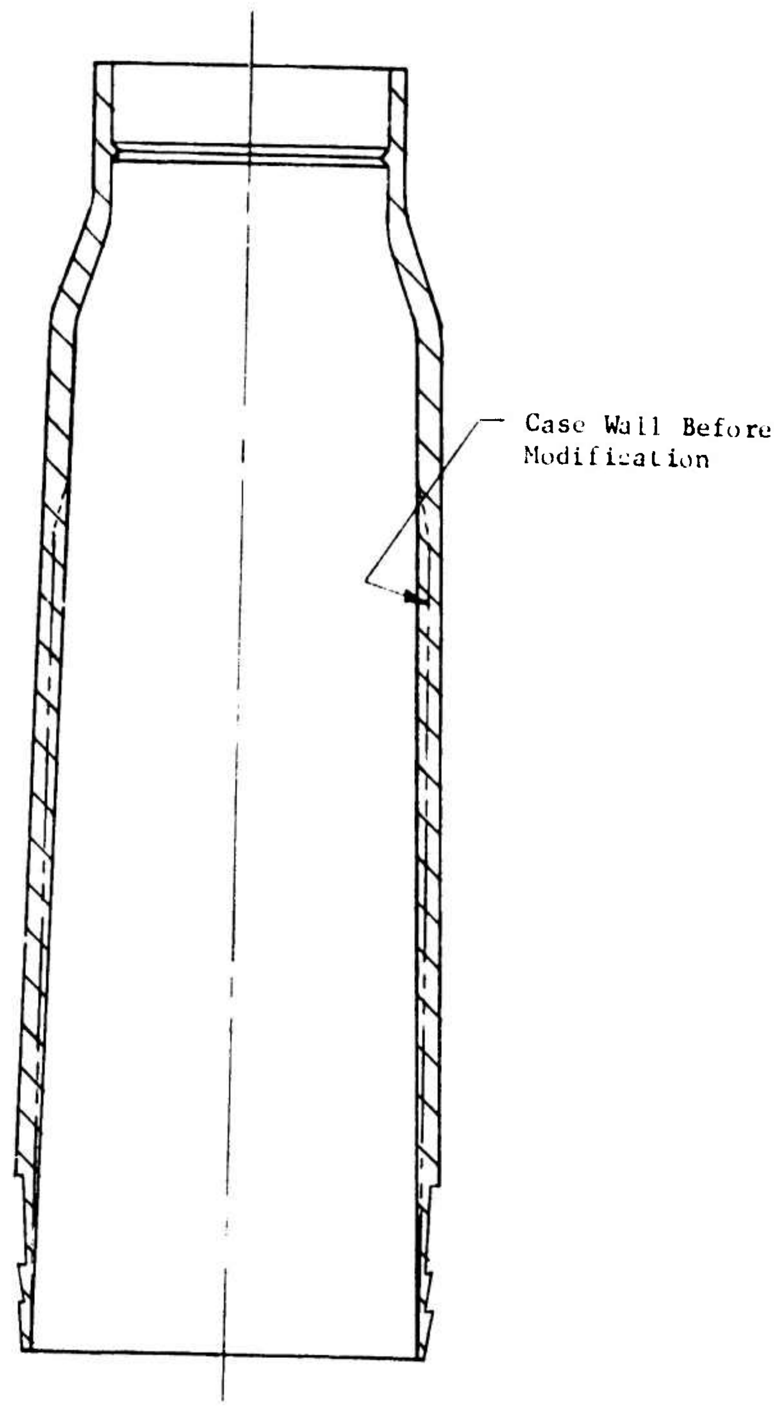


Figure 17. 20mm Case Wall Modification
Scale: 2/1

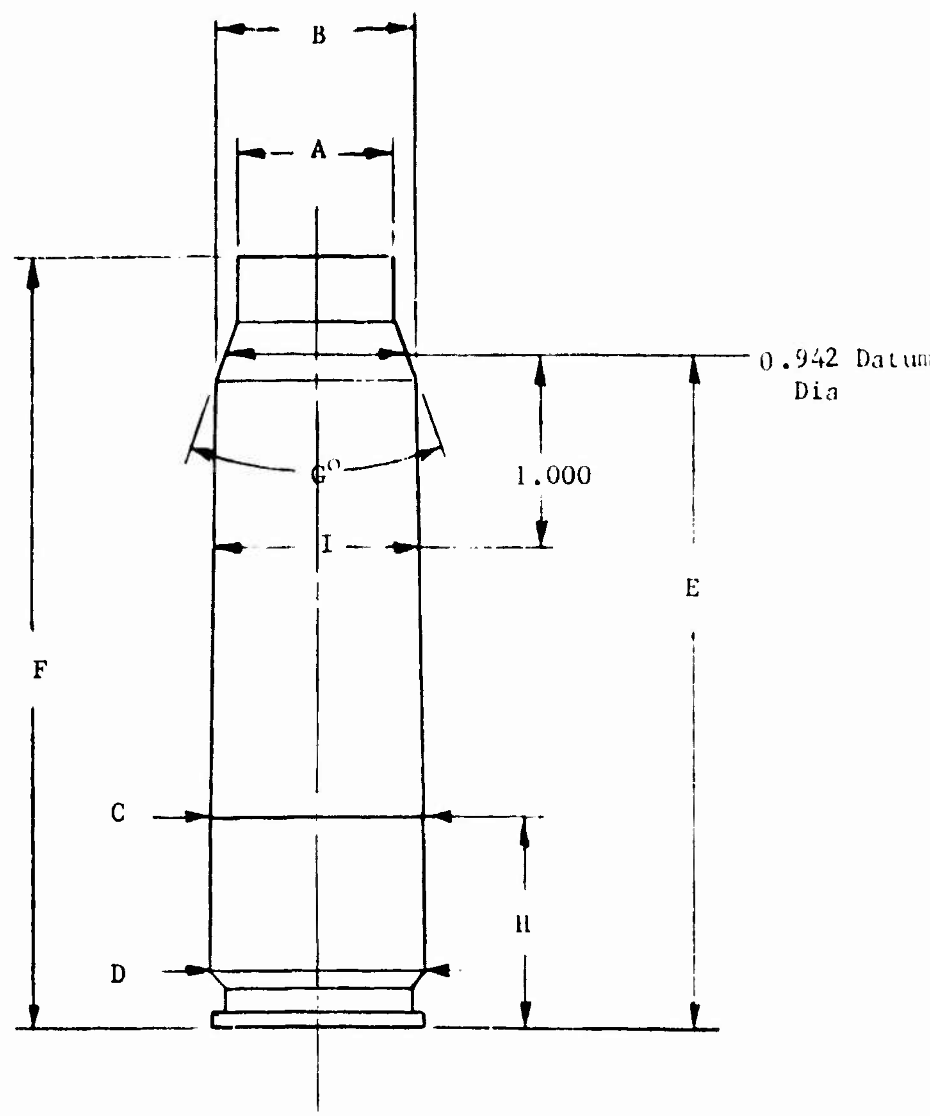


Figure 18. Dimensions Inspected on 20mm Plastic/Aluminum Case

Scale: 1/1

modified to increase this dimension. The increase amounted to 0.0045 inch on the diameter. This achieves a line-to-line contact with the minimum M61 chamber size at ambient temperatures.

Cases of 612 nylon/50 percent glass were molded in the altered mold, inspected, and fired at -65°F. Out of 24 fired, 4 cracked and 1 separation occurred, the first for this material. The failure rate had been reduced by the increased case size. The reason for the separation was not determined, but a tight fit between the case and base was suspected. Presently, there is a 0.015 inch squeeze on the diameter by the aluminum base at the plastic buttress area. Examination of the cracked cases indicated that this stressed area may be the source of the cracks at firing and may have caused the case separation. To verify this, a number of bases were modified to relieve the squeeze on the plastic at assembly. The fit was changed to line-to-line to a 0.002 press. Of 24 of these fired cold, 1 cracked and 2 separated, indicating that the squeeze on the plastic apparently had not been the cause of the cold failures.

Cases of type 12 nylon/50 percent glass were then molded for testing. These cases reflected the latest mold changes of increased outside diameter and heavier wall. Test results were highly successful in that no failures of any kind occurred at high or low temperatures. With successful initial tests at -65°F, firings were continued until a total of 100 rounds had been fired at -65°F, with no case failures. A total of 19 firings were made at 160°F which were all successful.

This is the best performance of any plastic material tested during the course of this contract, and it was incorporated into the final design specifications for the case.

During the course of this contract, a total of 1301 plastic case 20mm rounds has been test fired in the M61 and in a Mann barrel. The total includes those fired at high and low temperature extremes. The breakdown is as follows:

MANN BARREL	-	146
M61 (-65°F)	-	844
M61 (AMBIENT)	-	215
M61 (+160°F)	-	96
TOTAL		1301

Appendix III contains drawings of the 20mm plastic case mold. Appendix VI contains a record of test firings as related to mold changes.

During the course of development, 28 types of plastic materials were tested. They are listed in Table III.

TABLE III. LISTING OF TYPES OF PLASTIC MATERIALS TESTED

PLASTIC	PERCENTAGE OF FIBERGLASS BY WEIGHT	+ MANUFACTURER, SPECIFICATION
ETFE Fluoropolymer	Unfilled	DuPont (Tefzel 200)
ETFE Fluoropolymer	20	DuPont (Tefzel 2004)
66 Nylon	40	LNP, (RF-1008)
610 Nylon	40	LNP, (QF-1008)
610 Nylon	40	Fiberfil (G12/40 Nylafil)
610 Nylon	50	LNP, (QF-100-10)
612 Nylon	Unfilled	DuPont (Zytel 151)
612 Nylon	25	DuPont (Special Mix)
612 Nylon	33	DuPont (Zytel 77G33)
{612 Nylon (77%) 6 Nylon (23%)}	33	DuPont {Zytel 77G43 Zytel 211} Mix
612 Nylon	43	DuPont (Zytel 77G43)
612 Nylon modified	43	DuPont (FE 5024)
612 Nylon	45	LNP (IS-1009)
612 Nylon	50	DuPont (FE 5030)
Type 12 Nylon	30	Hüls (L 1930)
Type 12 Nylon *	50	Hüls (Thermofil N9-5000-FG)
Polycarbonate	Unfilled	G.E. (Lexan 141)
Polycarbonate	Unfilled	G.E. (Lexan 191)
Polycarbonate	Unfilled	G.E. (Lexan 500)
Polycarbonate	4	G.E. (Lexan 141)
Polycarbonate	8	G.E. (Lexan 141)
Polycarbonate	10	G.E. (Lexan 500)
Polycarbonate	40	G.E. (Lexan 500)
Polyester	Unfilled	Eastman (PTMT 6PRO)
Polyester	20	Eastman (PTMT 6G91)
Polyester	30	G.E. (Valox 420)
Polyethylene	Unfilled	DuPont (Alathon)
Polyethylene	30	DuPont (Alathon)

* Used on final design.
\+ See Appendix V for manufacturer's addresses.

2. 30MM CARTRIDGE CASE

Work was initiated with the establishment of the basic size and configuration of the 30mm case based upon the stated parameters. It was desired that the internal propellant volume be at least 10 cubic inches and the cartridge case rim be 50mm in diameter. Using these guidelines and including a slight external taper to aid extraction, an internal taper for easy mold core removal, and sizing the neck for 30mm, the basic shape was evolved. Stress calculations predicted that 3 buttresses in the joint would be required to withstand the bearing stress at the tooth surfaces imposed by the expected case tensile loads.

A mold was designed and constructed, drawings of which (53595-10006 sheets 1 and 2) are included in Appendix II of this report. The core which forms the internal cavity was supported front and back to prevent deflection of the core during the injection cycle. The molding was accomplished on a New Britain 3-ounce capacity molding machine which has a clamping force of 75 tons.

A Mann barrel was fabricated on a subcontract to Mathewson Tool Company, Orange, Connecticut. The 30mm barrel is 90 inches long with gain twist rifling ranging from 0° - 10' at the breech to 8° - 53' at the muzzle. The chamber is a separate component threaded onto the barrel and the breech contained a percussion firing mechanism.

Based on the success at this time with 612 nylon/43 percent glass on the 20mm case program, this material was chosen initially for fabrication of 30mm case bodies. The material performed well from the initial Mann barrel tests and is therefore specified for the final design.

A total of 25 cartridges was test fired under various conditions during this developmental test program. In all tests, the propellant was CIL 1379C, and the projectile was the 30mm target practice projectile. T328, weighted to 5000 grains. The use of CIL 1379C propellant was suggested by the government program manager based upon satisfactory results with this propellant for other 30mm applications.

The first three tests were charge development tests conducted to ascertain the correct amount of the propellant. The charge weight was established at 160 grams. The results of the next seven tests, conducted with the established weight of the propellant, 160 grams, were excellent. There was no evidence of damage to the plastic/aluminum case, nor separation between the aluminum base and plastic body. The measured velocity averaged 3508 fps with extremes of 3491 and 3515 fps. All of these values are close to the muzzle velocity of 3500 fps which was stipulated in the contract. The peak pressures in the gun chamber ranged from 38,000 psi to 43,300 psi with an average of 40,000 psi. These are well within the peak pressures experienced in gun chambers which normally experience peak pressures on the order of 50,000 to 60,000 psi At this point, basic feasibility within the scope of the contract had been established.

Although temperature extremes testing was not a requirement, it was felt that additional testing conducted at -65°F would be useful in isolating possible problem areas for future development. For these tests, the Mann barrel chamber and round were conditioned at -65°F as explained in Section III.

It was immediately discovered that the XM115 primer would not ignite the propellant charge at -65°F. A booster charge of one gram of black powder was added adjacent to the XM115 primer. The round was fired at -65°F and the projectile velocity was considerably higher at 4274 fps. The case, however, showed no evidence of damage.

During these first tests, the major concern was to ascertain the integrity of the plastic/aluminum case while attaining a prescribed velocity at ambient and then low temperature conditions. However, one recorded chamber pressure curve appeared to indicate an excessive time delay between primer hit and peak pressure. While this observation was incidental to the purpose of the test, the apparent time delay, nevertheless, was detrimental to automatic gun operation. The time delay coupled with the failure of the XM115 primer to ignite the CIL 1379C propellant under low temperature conditions prompted the design of a booster which, therefore, could serve a dual purpose of reducing the time delay and eliminating misfire at low temperatures.

A booster tube assembly using a No. 111 percussion primer and a booster charge of 0.3 gram of boron potassium nitrate was designed and approved by AFATL in June 1970. The booster assembly consisted of parts No. 53593-40004, 53593-40008, and 53593-40009, the details of which are submitted in Appendix II of this report.

Seven ambient temperature and six low temperature tests were conducted using the booster tube assembly. The ambient temperature tests showed an average projectile velocity of 3554 fps, slightly higher than the average with the XM115 primer. Projectile velocities for the various low temperatures were slightly below the 3508 fps average.

In all the above tests, no evidence of plastic case cracking or separation from the aluminum base has appeared. There were no misfires at low temperatures, and the time delay from primer hit to peak pressure was approximately 2 milliseconds, which is considered acceptable.

Table IV is a record of the firing data recorded during the testing of the 30mm plastic/aluminum case.

Drawings of the 30mm case mold are included in Appendix IV.

TABLE IV. FIRING DATA RECORDED DURING TESTING OF 30MM PLASTIC/ALUMINUM CASE

TEST NO.	CHARGE WEIGHT (GRAMS)	PRIMER	TEMPERATURE	PEAK PRESSURE (PSI)	VELOCITY (FPS)	REMARKS
1	100	XM115	Ambient	15,000	2404	
2	150			39,400	3413	
3	170			53,000	3731	
4	160			42,000	3546	
5				37,000	3497	
6				40,800	3515	
7				38,000	3521	
8				39,500	3491	
9				39,500	3497	
10			Ambient	42,000	3509	
11			-65°F	Note 1	Note 1	Note 1
12		XM115	-65°F	Note 4	4274	Note 2
13		No. 111	Ambient	Note 4	3584	Note 3
14				45,000	3546	
15				45,000	3546	
16			Ambient	43,500	3521	
17			-65°F	41,800	3436	
18		No. 111	-65°F	Note 4	3460	Note 3
19		XM115	Ambient		3571	
20		XM115			3571	
21		No. 111	Ambient		3534	Note 3
22			-65°F		3425	
23					3370	
24					3413	
25	160	No. 111	-65°F	Note 4	3413	Note 3

NOTES:
1. PROPELLANT FAILED TO IGNITE
2. BOOSTER - 1 GRAM OF BLACK POWDER
3. BOOSTER - 0.3 GRAM OF BORON POTASSIUM NITRATE
4. PRESSURE NOT TAKEN

SECTION V

CONCLUSIONS AND RECOMMENDATIONS

The results of this program indicate that basic feasibility for the 20mm and 30mm plastic/aluminum cartridge cases has been established. The velocity requirements have been met, and successful operation at temperature extremes has been demonstrated with a limited number of firings.

The 20mm plastic/aluminum cartridge case has been tested in the M61 cannon at all temperatures with resulting satisfactory case performance and normal gun operation. The most severe mode of operation concerning case integrity was found to be firing at the low temperature extreme of -65°F. Therefore, the main effort on the program was concentrated on the elimination of the case failures that occurred at low temperatures. Based on the limited number of successful test firings at the end of the program (100 rounds at -65°F, and 4300 rounds-per-minute), the cold failure problem appears to have been eliminated. Firing at ambient temperatures did not present a particular problem, and difficulties encountered at high temperature (160°F) were not as severe as those encountered at cold temperatures and were quickly eliminated. The overall performance matches that of the M103 brass cartridge case in resulting projectile velocity and pressure. With further development, the plastic/aluminum cartridge case could be a suitable replacement for the M103 cartridge case.

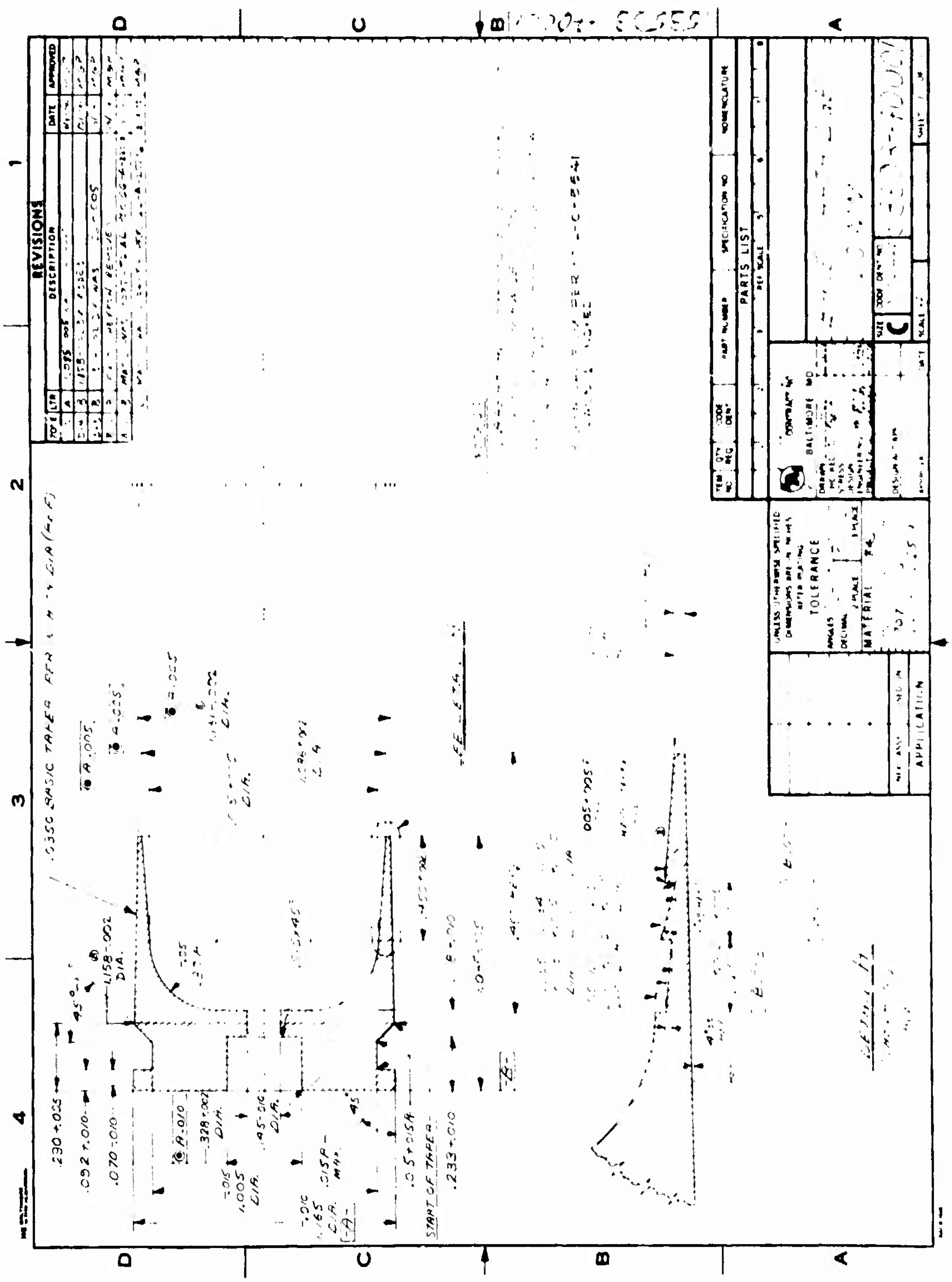
Further work is necessary in the area of quality assurance investigations which would involve the testing of larger quantities of rounds. This would establish limits on dimensional tolerances and on manufacturing processes including molding temperatures and pressures. The case should be tested and made compatible with the various existing feed systems both link and linkless. Further environmental testing is suggested with additional firings at the temperature extremes. Also necessary are the standard environmental tests including rain, temperature shock, immersion, humidity, salt spray, dust, altitude and shock.

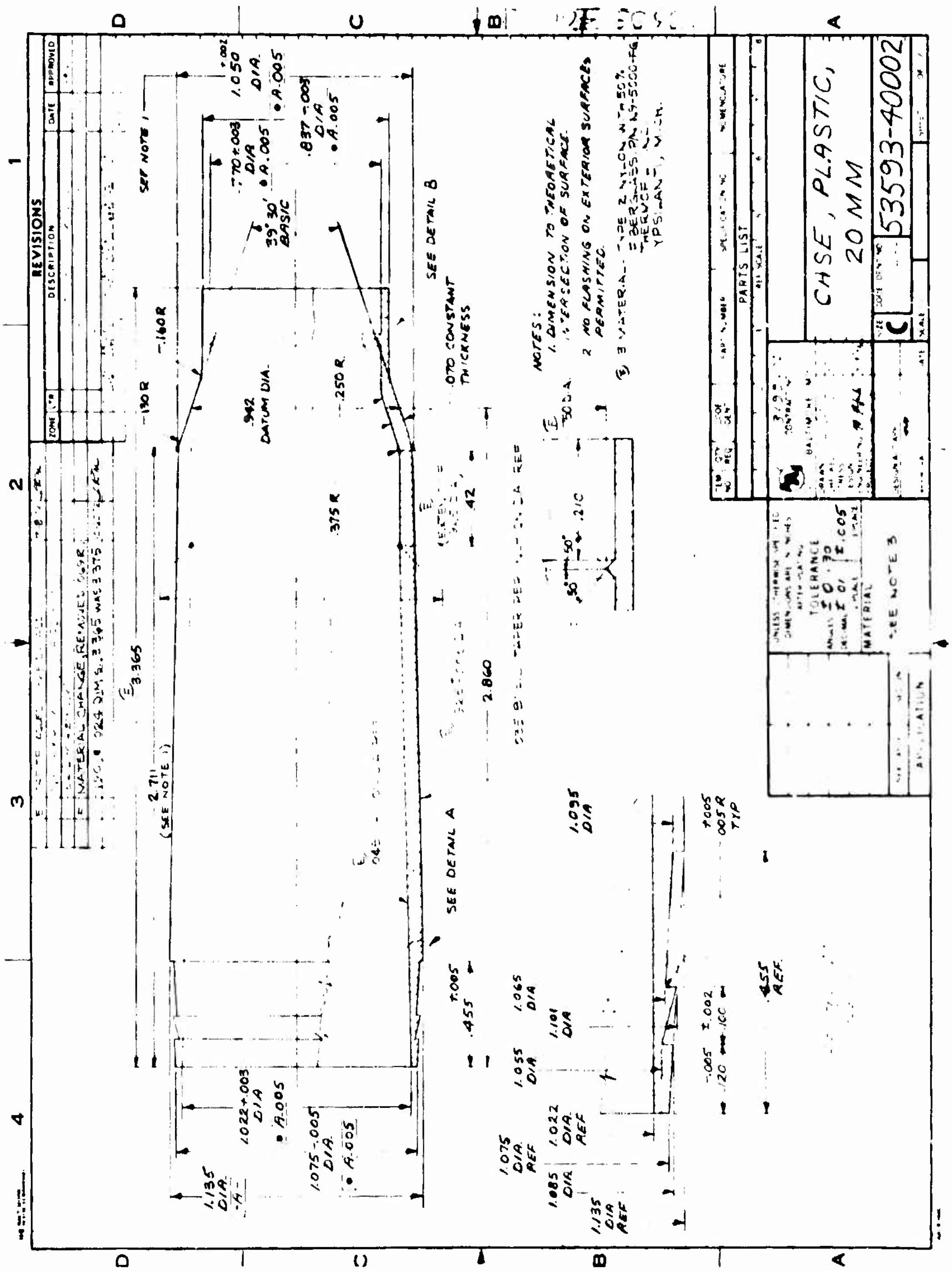
The 30mm case has been tested successfully in the Mann barrel at ambient temperatures and at -65°F. Further work should involve development of an ignition system that would reliably ignite the large propellant charge to keep time delay to a minimum. With the development of a high rate of fire weapon, further testing with the 30mm plastic/aluminum case in the weapon should be conducted. It is felt that the case would be a candidate for use in the ammunition for the new 30mm weapon.

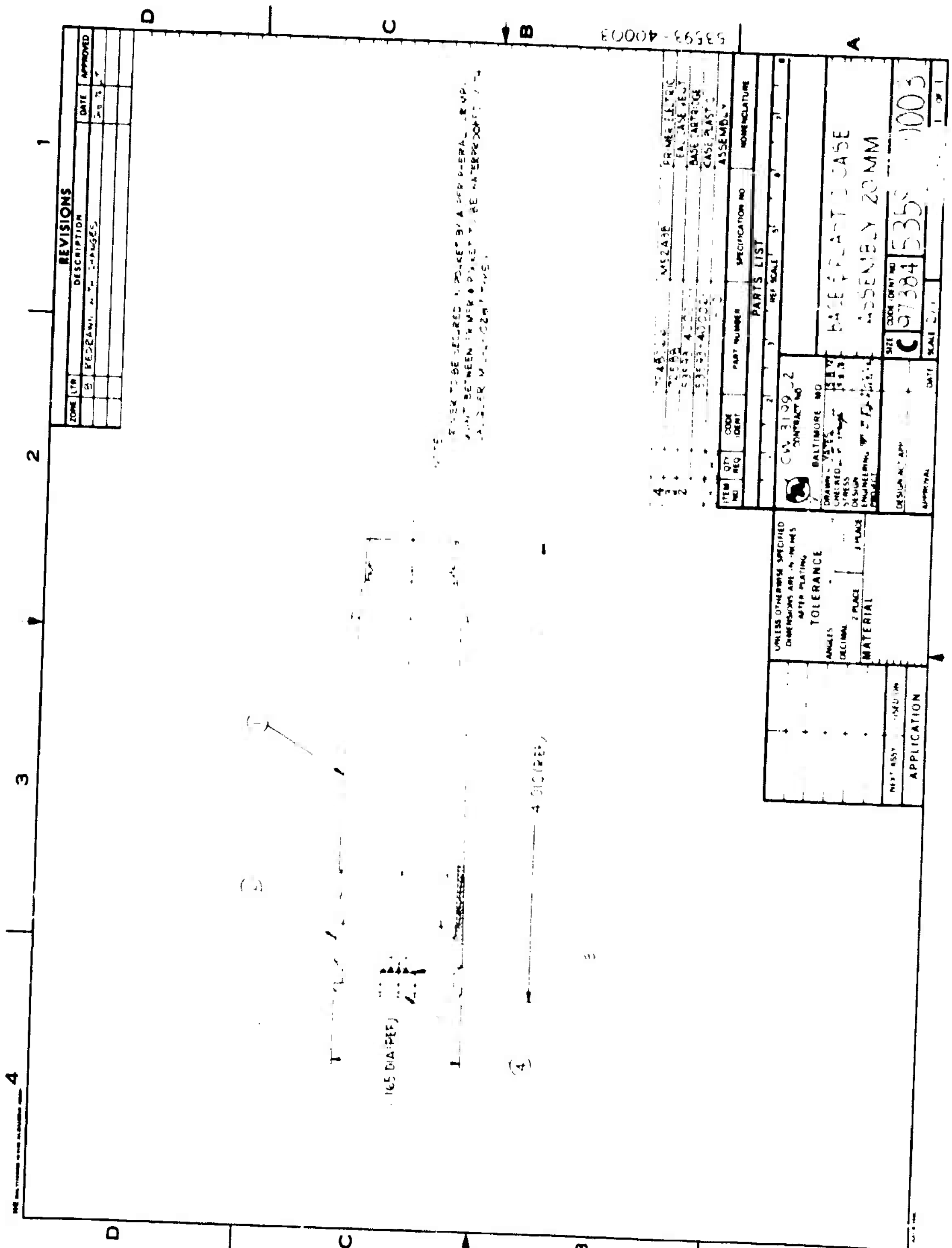
APPENDIX I

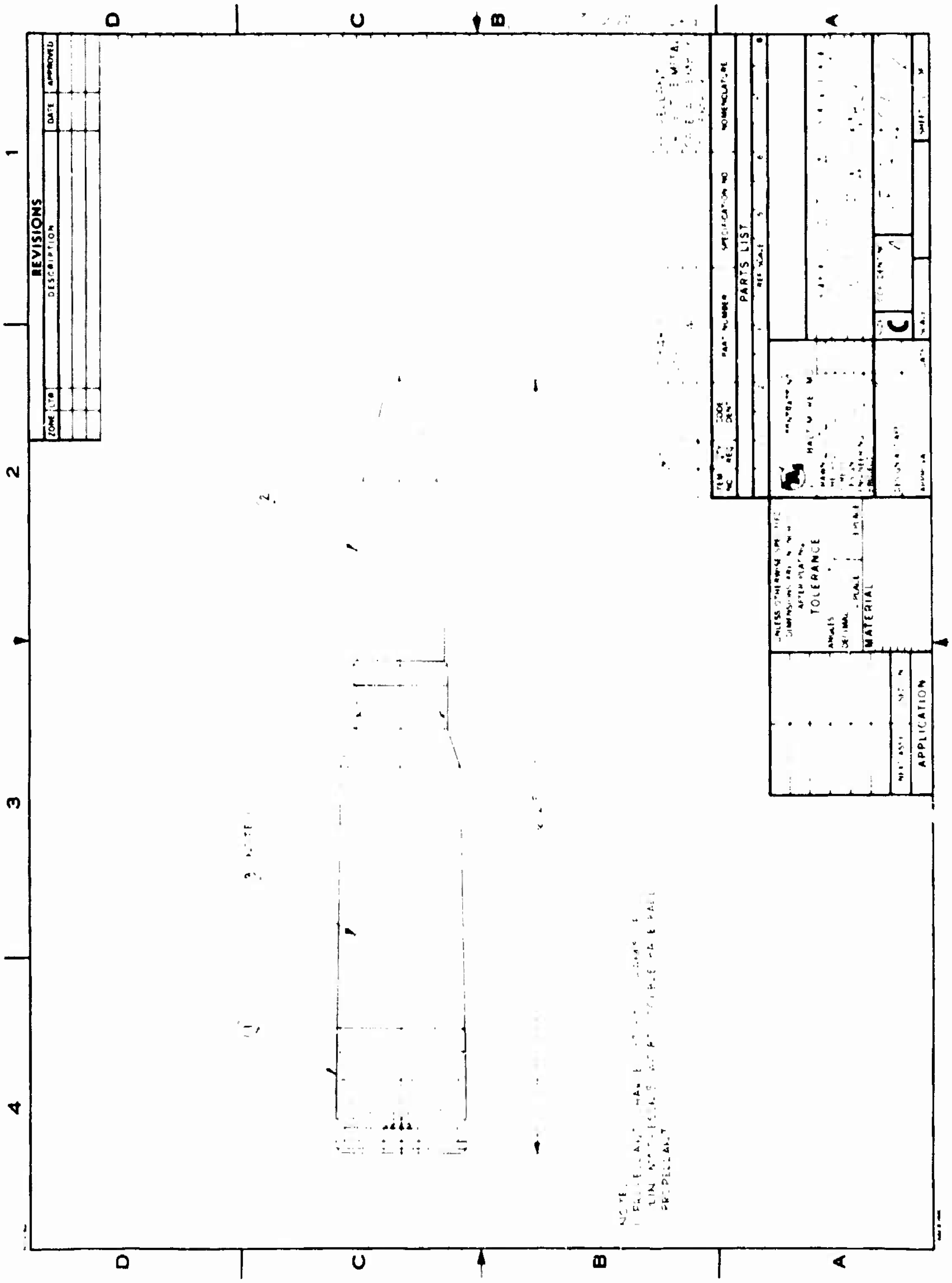
20MM CARTRIDGE CASE DRAWINGS

53593-40001	Cartridge Base
53593-40002	Plastic Body
53593-40003	Case Assembly
53593-40012	Cartridge Assembly


REVISIONS
DESCRIPTION
DATE
APPROVED
PARTS LIST
NOMENCLATURE
BALTIMORE MD
TOLERANCE
MATERIAL
APPLICATION
START OF TAPER
.233+.010
.230+.025
.092+.010
.070-.010
.1158-.002 DIA.
.328-.002 DIA.


REVISIONS
SEE NOTE 1
SEE DETAIL A
SEE DETAIL B
.942 DATUM DIA.
.070 CONSTANT THICKNESS
NOTES:
1. DIMENSION TO THEORETICAL INTERSECTION OF SURFACE.
2. NO FLASHING ON EXTERIOR SURFACES PERMITTED.
PARTS LIST
CHASE, PLASTIC, 20MM
53593-40002


REVISIONS
DESCRIPTION
PARTS LIST
BALTIMORE, MD.
TOLERANCE
MATERIAL
APPLICATION
.165 DIA (REF)



(The Reverse of this Page is Blank)

APPENDIX II

30MM CARTRIDGE CASE DRAWINGS

53593-40004 Base (for Booster)

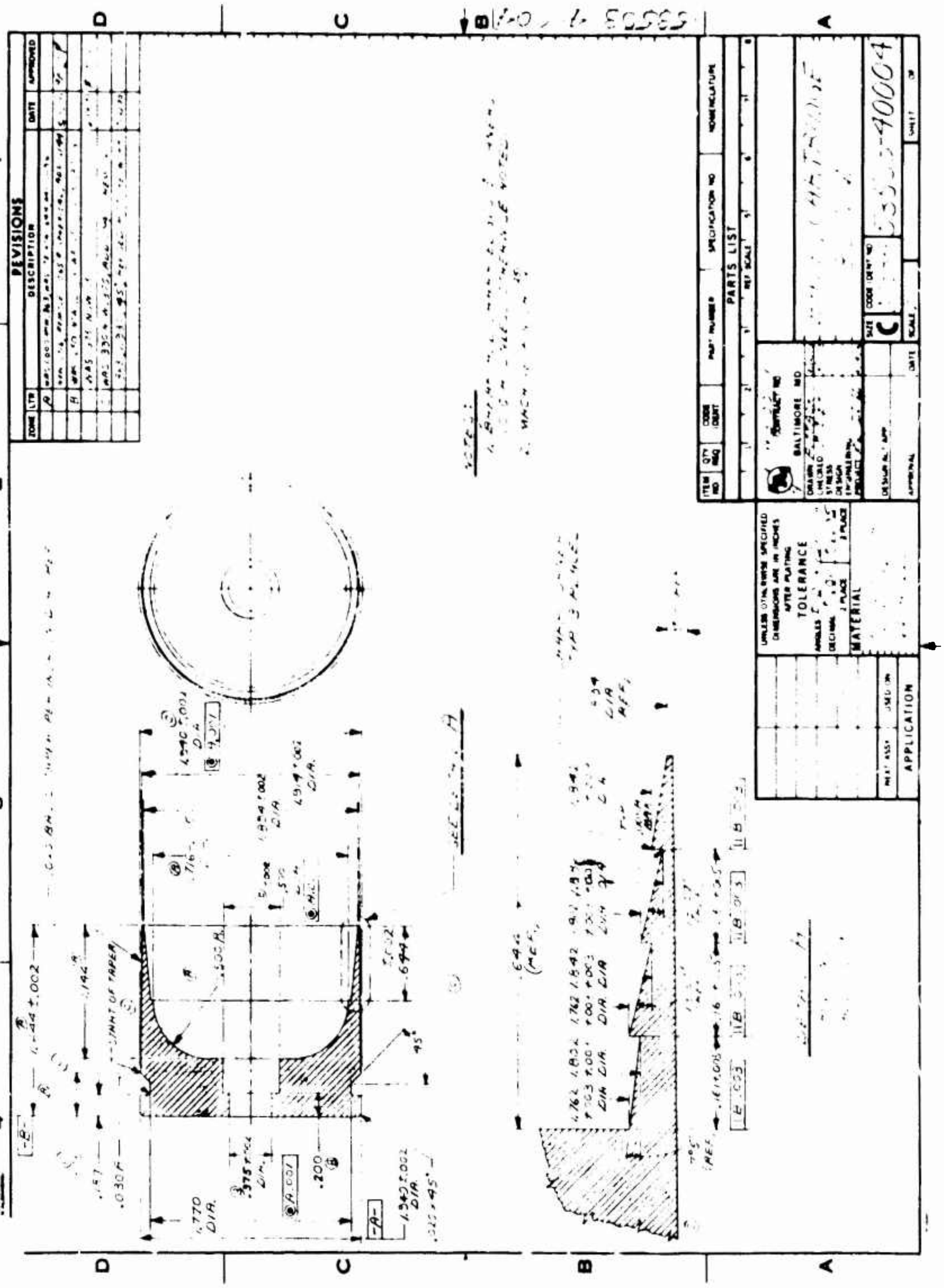
53593-40005 Plastic Case

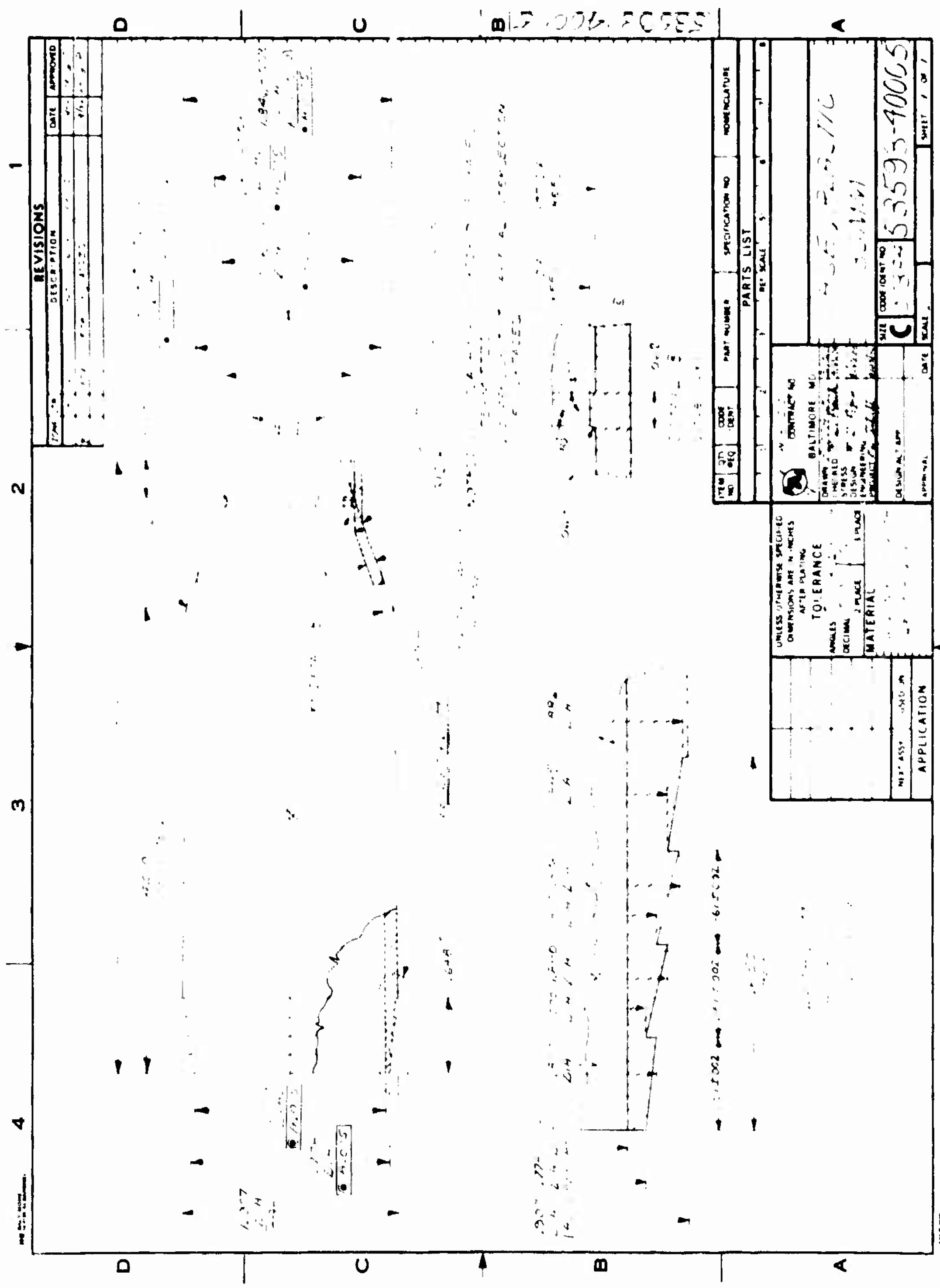
53593-40006 Case Assembly

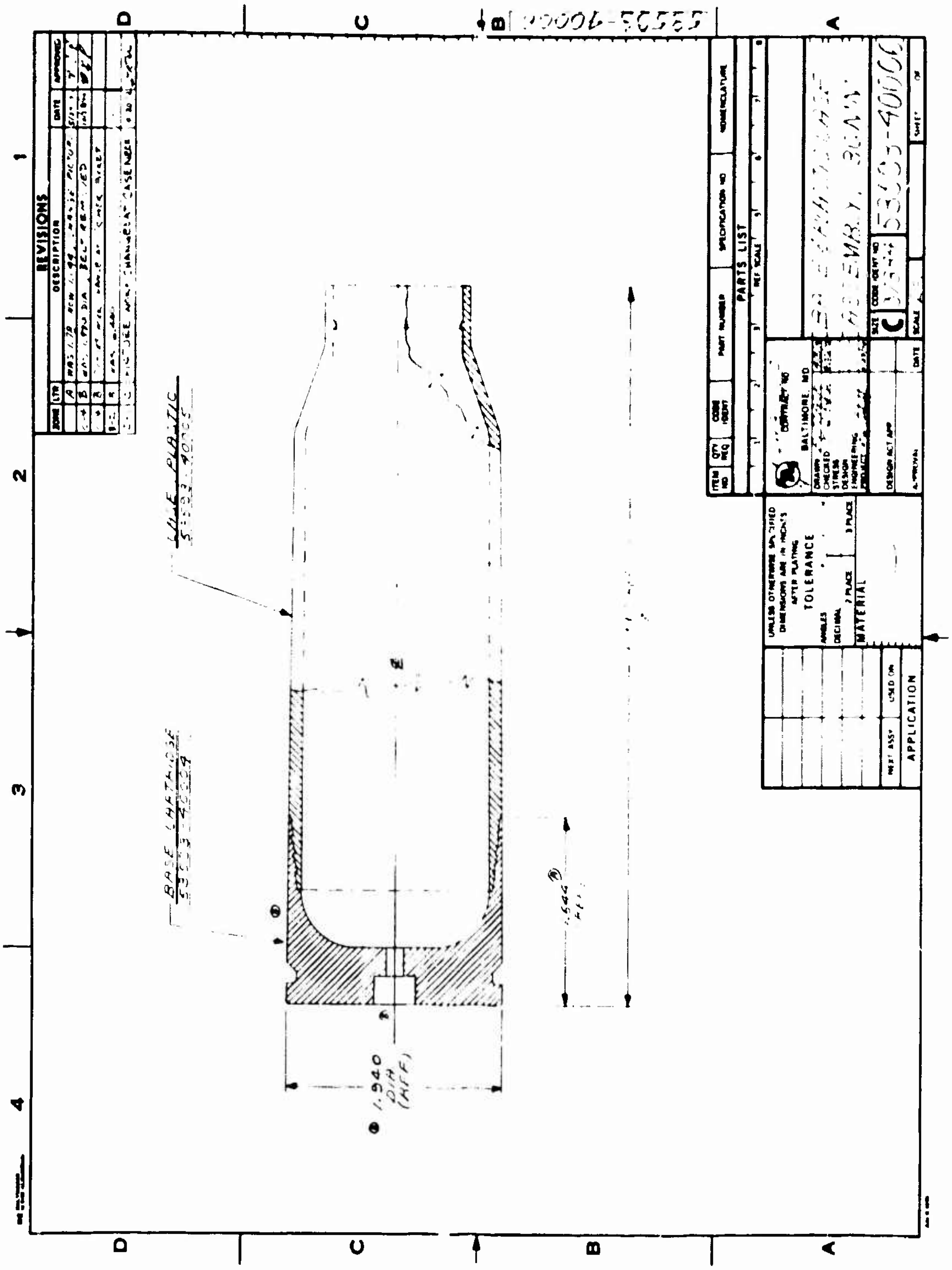
53593-40008 Primer Booster

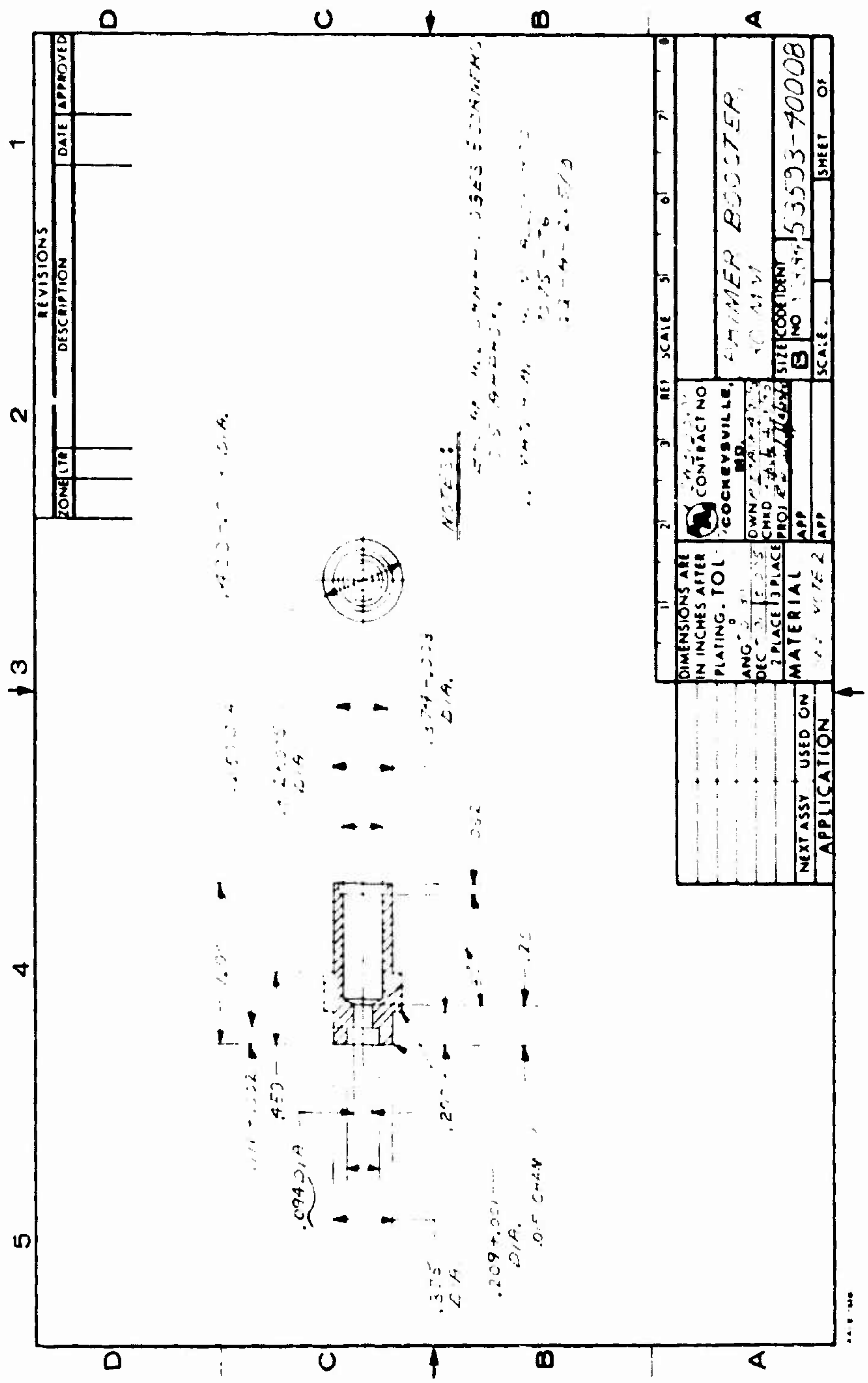
53593-40009 Rupture Disk

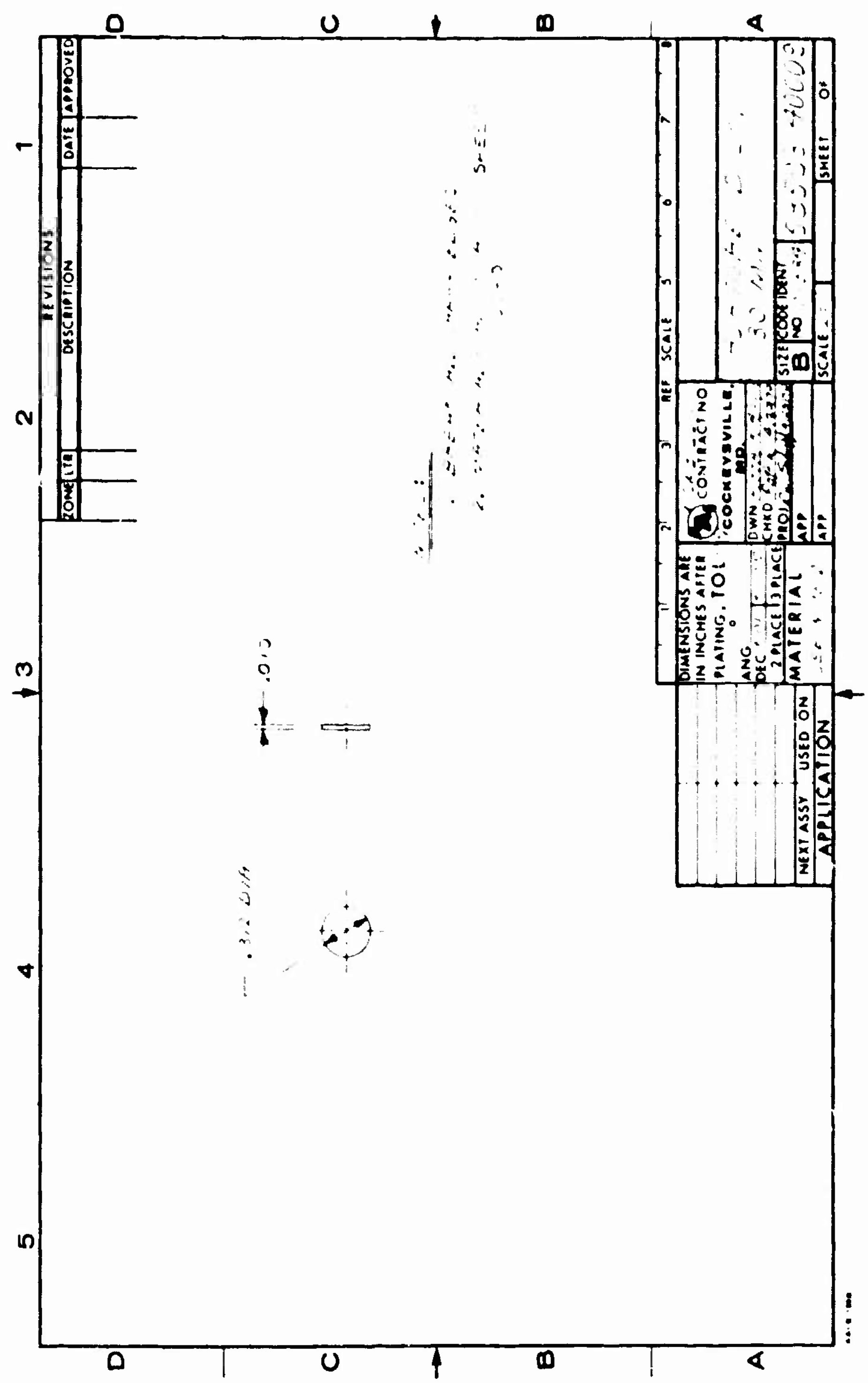
53593-40011 Base (for XM115 Primer)

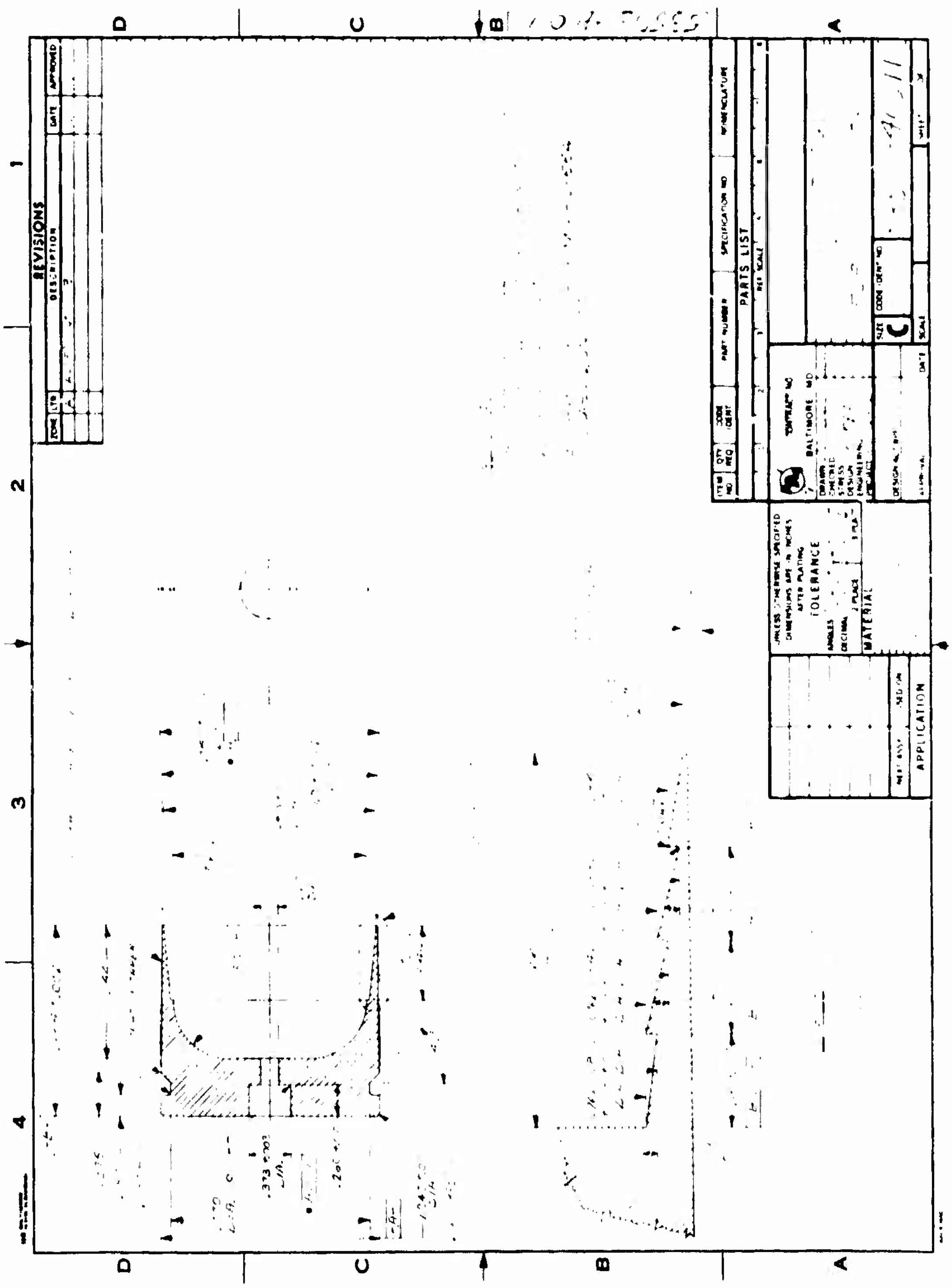

REVISIONS
PARTS LIST
BALTIMORE MD
TOLERANCE
MATERIAL
APPLICATION


REVISIONS
PARTS LIST
TOLERANCE
MATERIAL
APPLICATION
BALTIMORE, MD
53595-40065


REVISIONS
DESCRIPTION
PARTS LIST
BALTIMORE, MD
TOLERANCE
MATERIAL
APPLICATION
1.940
DIA


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
NOTES:
DIMENSIONS ARE IN INCHES AFTER PLATING. TOL
ANG
DEC
2 PLACE
3 PLACE
MATERIAL
CONTRACT NO
COCKEYSVILLE, MD.
DWN
CHKD
PROJ
APP
PRIMER BOOSTER
SIZE
B
CODE IDENT NO
53593-70008
SCALE
SHEET
OF
NEXT ASSY
USED ON
APPLICATION


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
DIMENSIONS ARE IN INCHES AFTER PLATING, TOL
ANG
DEC
2 PLACE
3 PLACE
MATERIAL
CONTRACT NO
COCKEYSVILLE, MD.
DWN
CHKD
PROJ
APP
REF SCALE
SIZE
B
CODE IDENT NO
SCALE
SHEET
OF
NEXT ASSY
USED ON
APPLICATION
.010

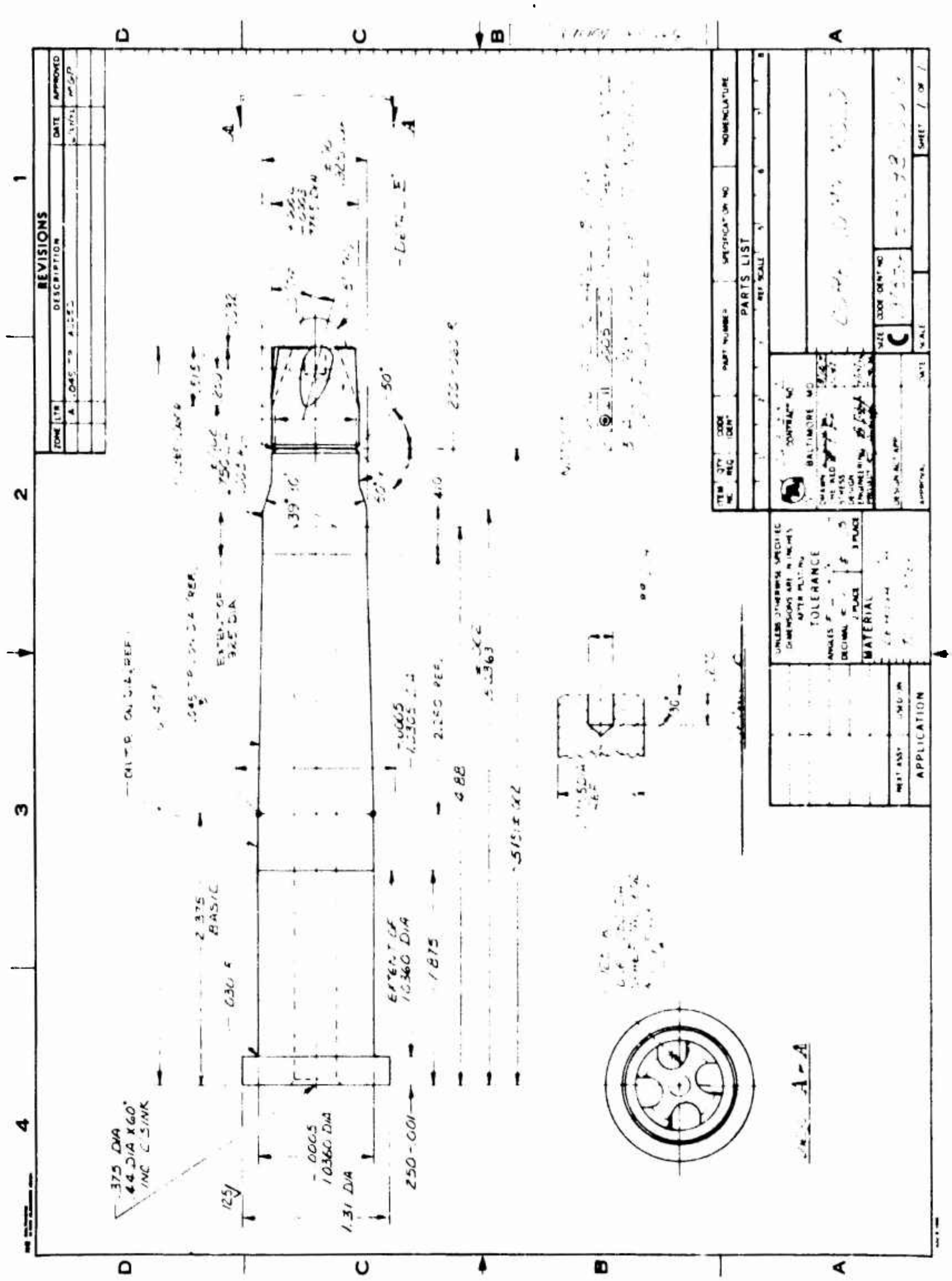


(The reverse of this page is blank)

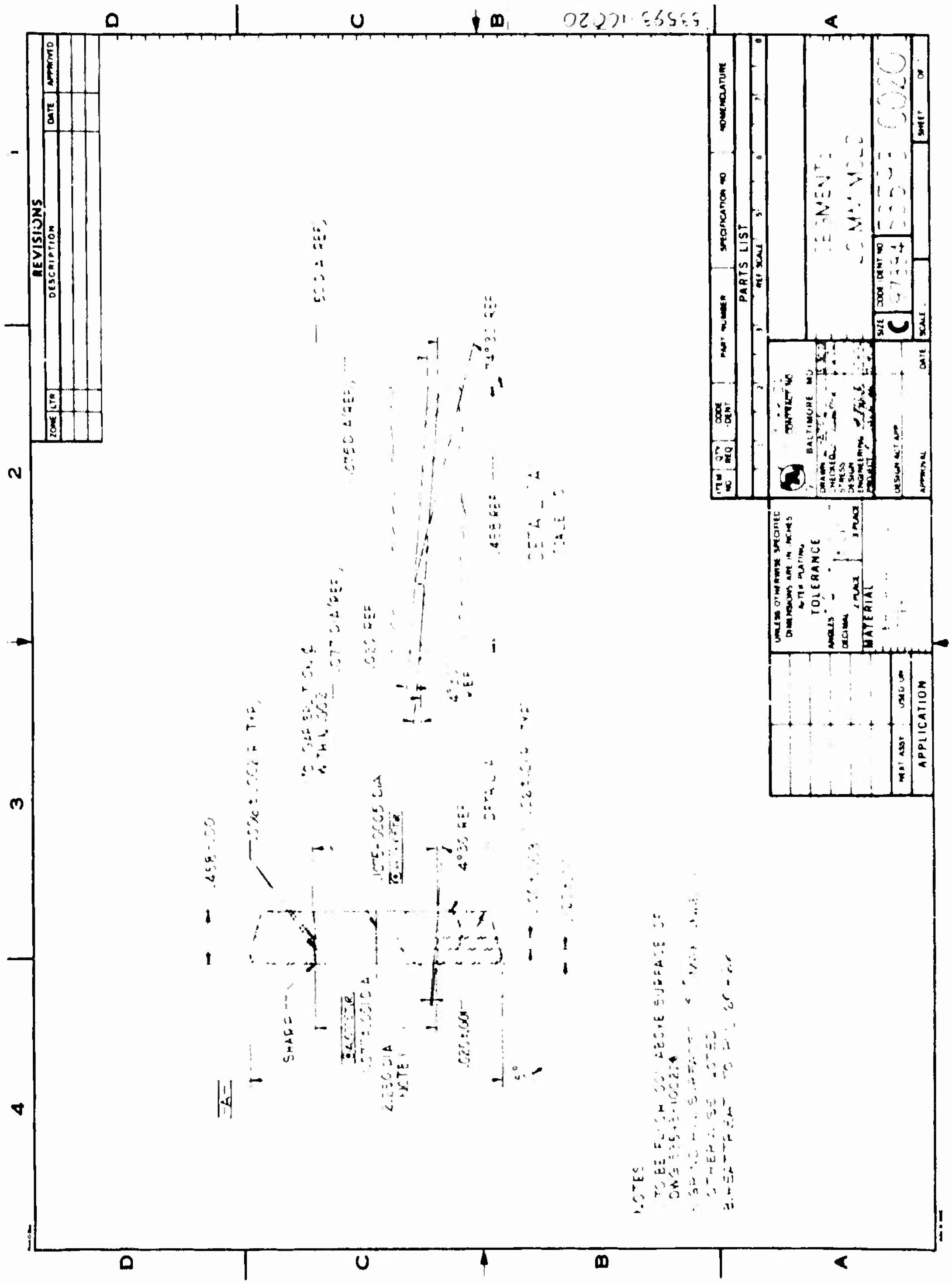
APPENDIX III

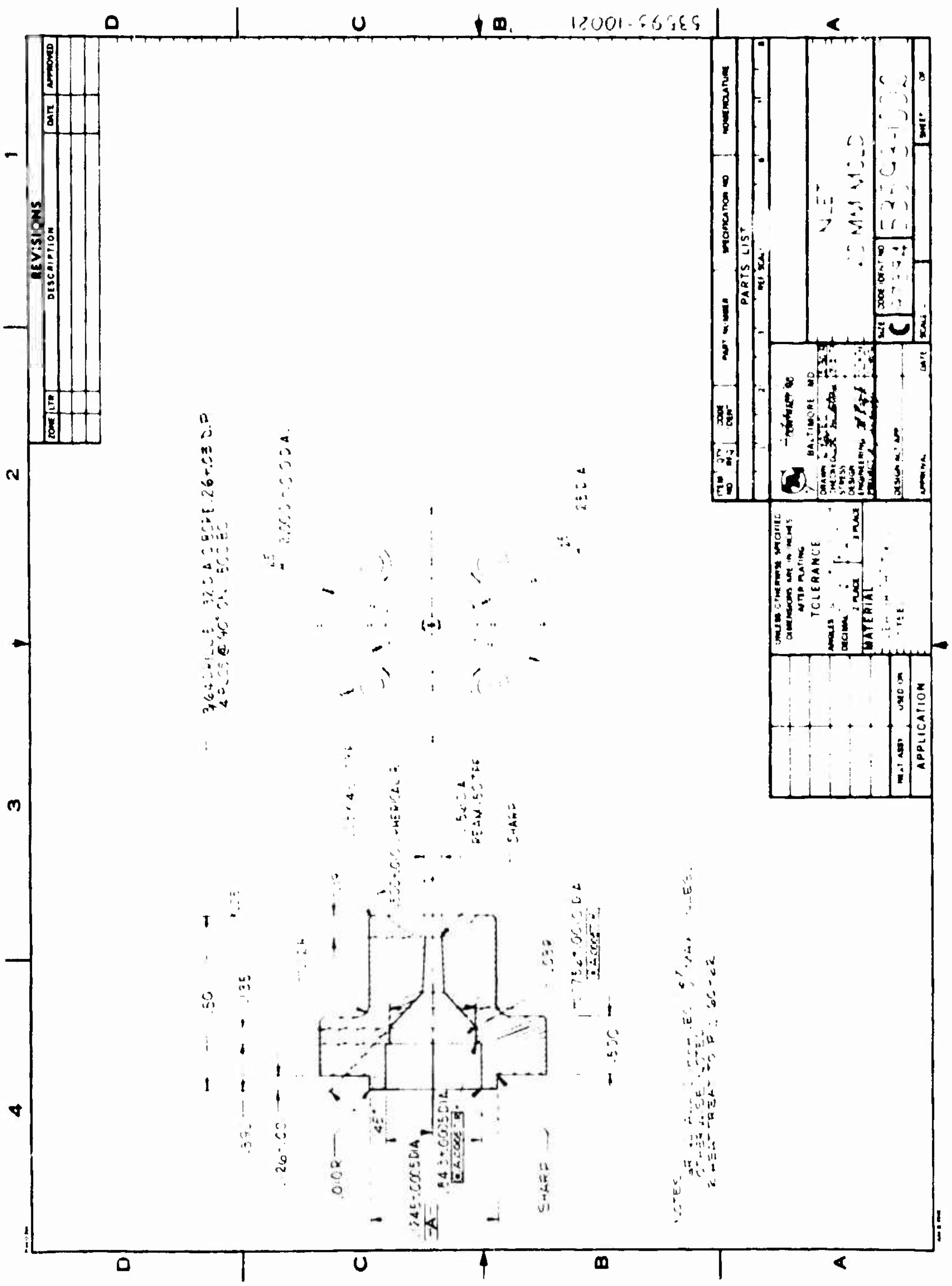
20MM MOLD DRAWINGS

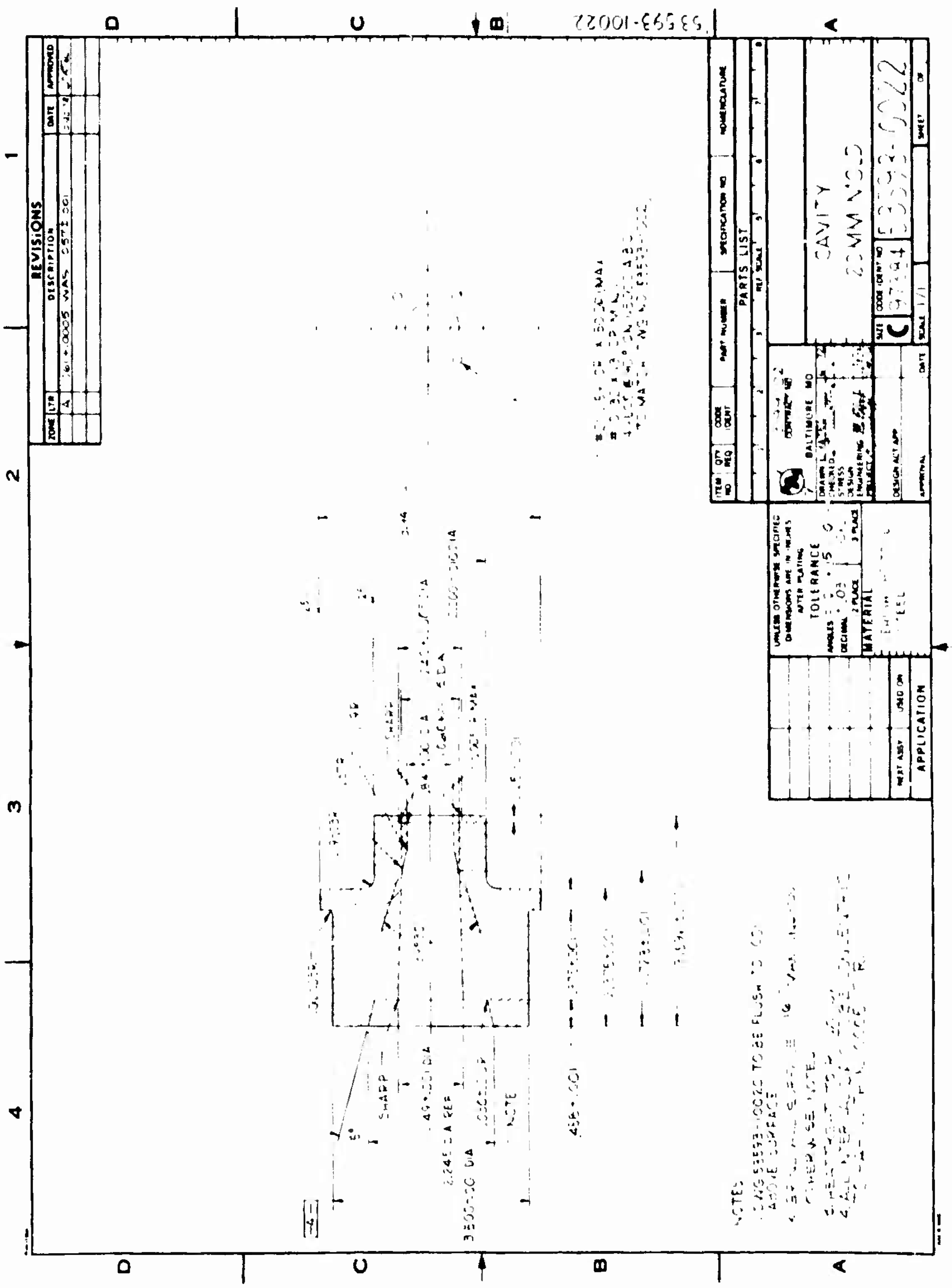
53593-10019	Core
53593-10020	Segments
53593-10021	Inlet
53593-10022	Cavity
53593-10023	Stripper
53593-10024	Rod
53593-10025	Mold Assembly

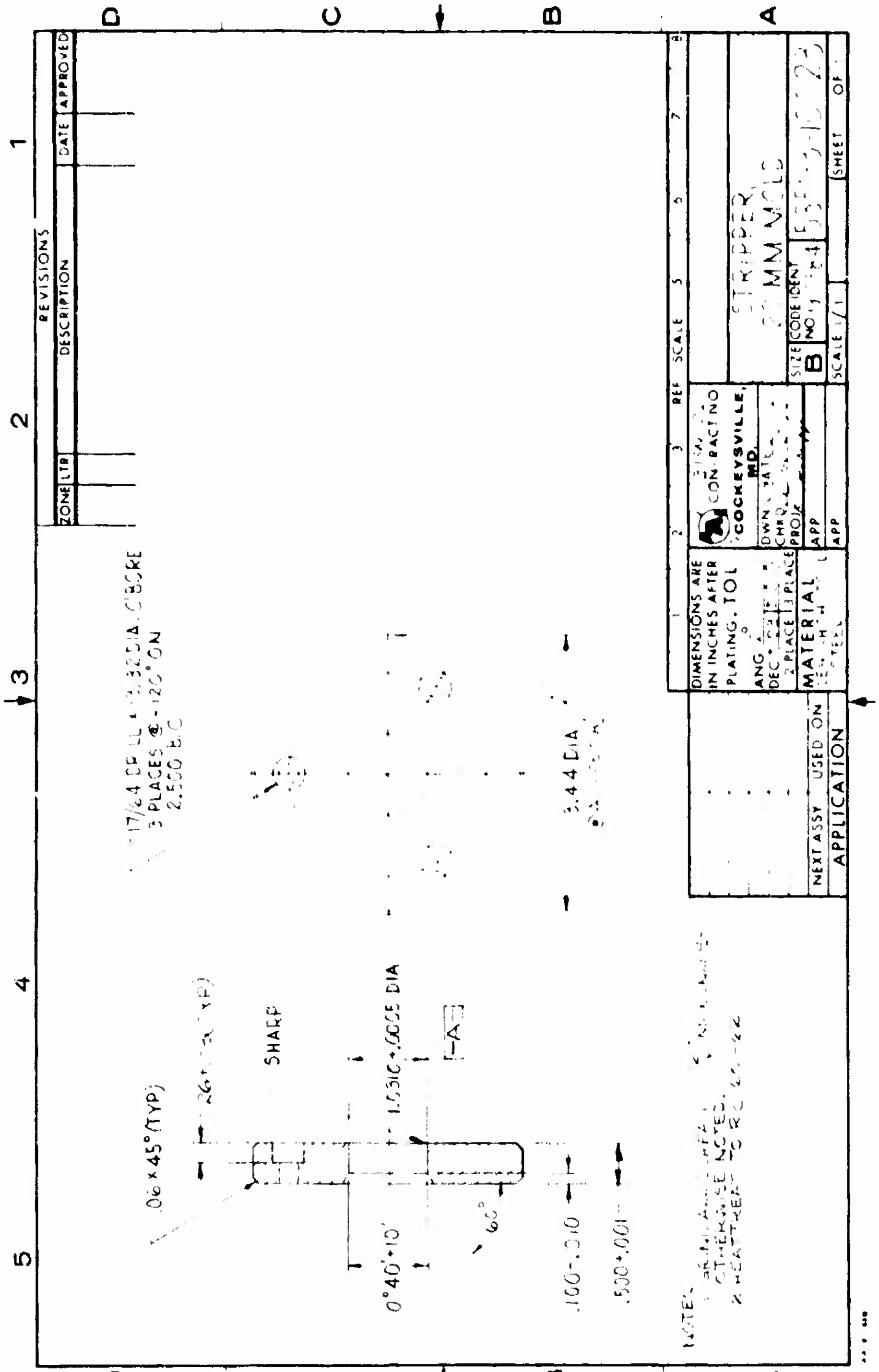


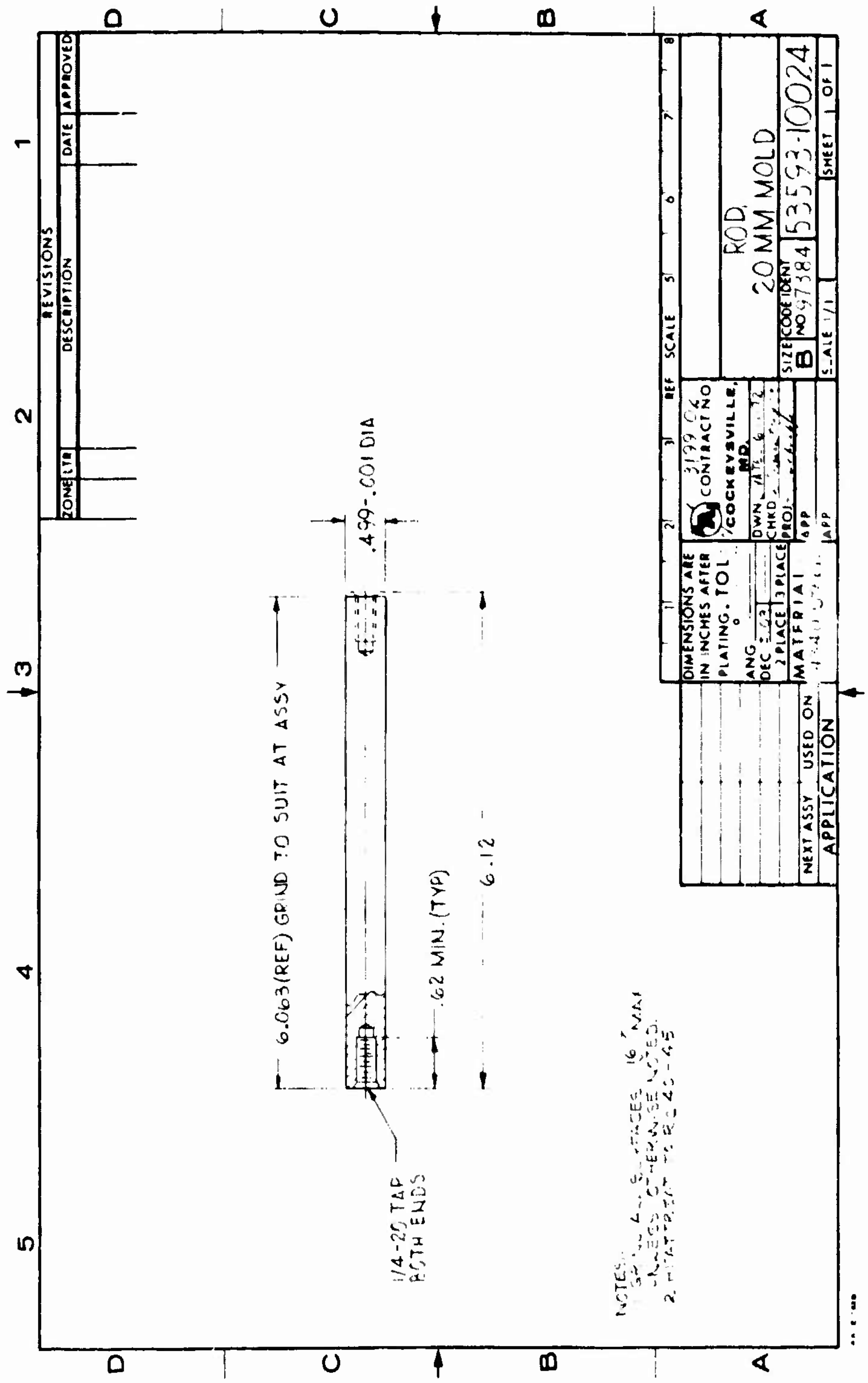
REVISIONS
PARTS LIST
.375 DIA
.44 DIA X 60°
INC C SINK
2.375
BASIC
1.31 DIA
250-.001
EXTENT OF
1.0360 DIA
1.875
4.88
EXTENT OF
.325 DIA
DETAIL E
A-A
BALTIMORE MD
TOLERANCE
MATERIAL
APPLICATION


REVISIONS
DESCRIPTION
DATE
APPROVED
PARTS LIST
BALTIMORE MD
TOLERANCE
MATERIAL
APPLICATION

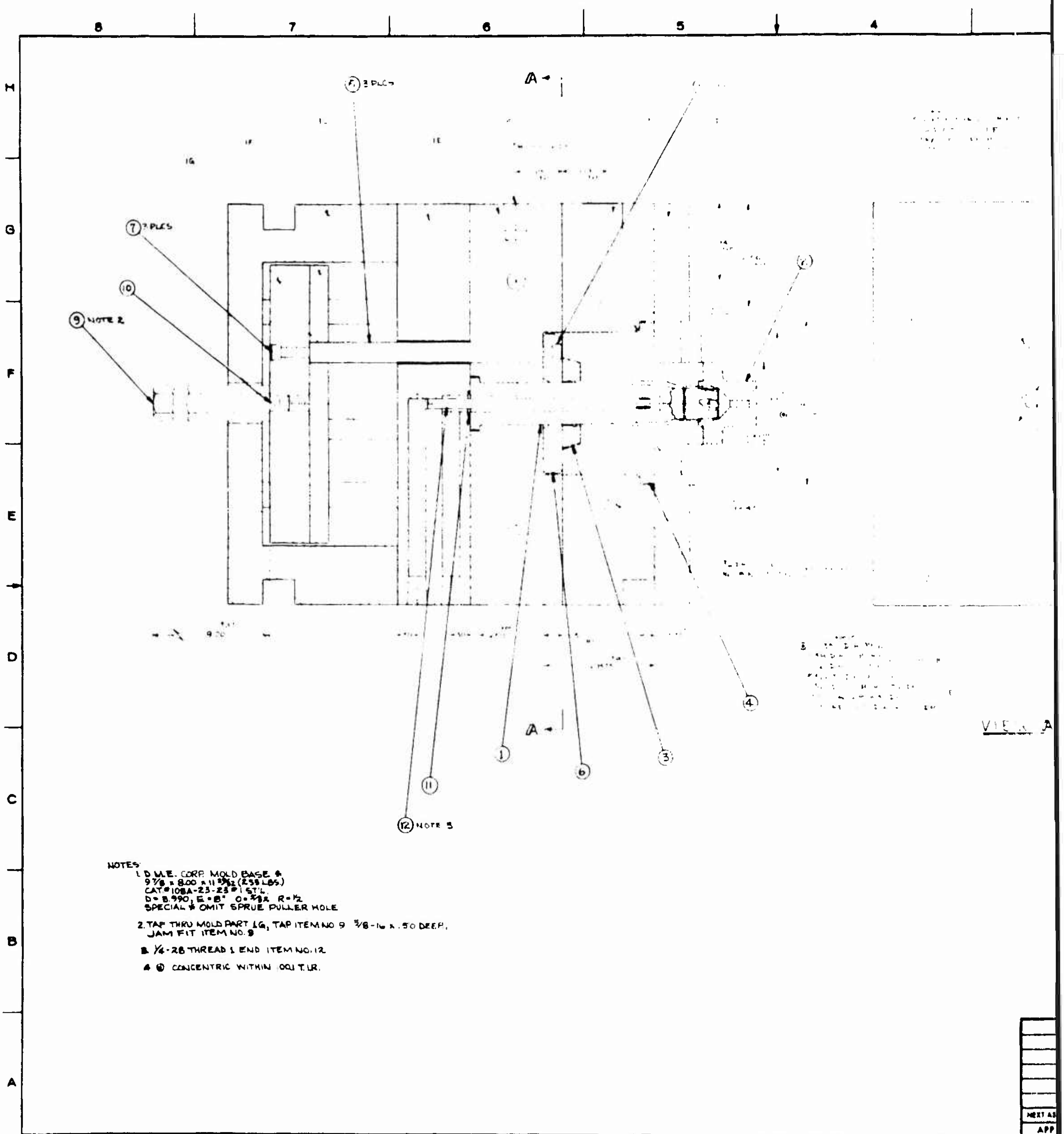



REVISIONS
PARTS LIST
CAVITY
BALTIMORE MD
TOLERANCE
MATERIAL
APPLICATION
53593-10022


REVISIONS
ZONE
LTR
DESCRIPTION
DATE
APPROVED
.06 x 45° (TYP)
SHARP
1.5310 +.0005 DIA
3.44 DIA
COCKEYSVILLE, MD.
DIMENSIONS ARE IN INCHES AFTER PLATING. TOL
MATERIAL
NEXT ASSY
USED ON
APPLICATION
SIZE
CODE IDENT NO
B
SCALE 1/1
SHEET
OF



(The reverse of this page is blank)



NOTES:

1. D.M.E. CORP. MOLD BASE & 9 7/8 x 8.00 x 11 3/32 (258 LBS.) CAT# 108A-23-23 #1 ST'L. D = 8.990, E = 8" O = 3/32 R = 1/2 SPECIAL & OMIT SPRUE PULLER HOLE

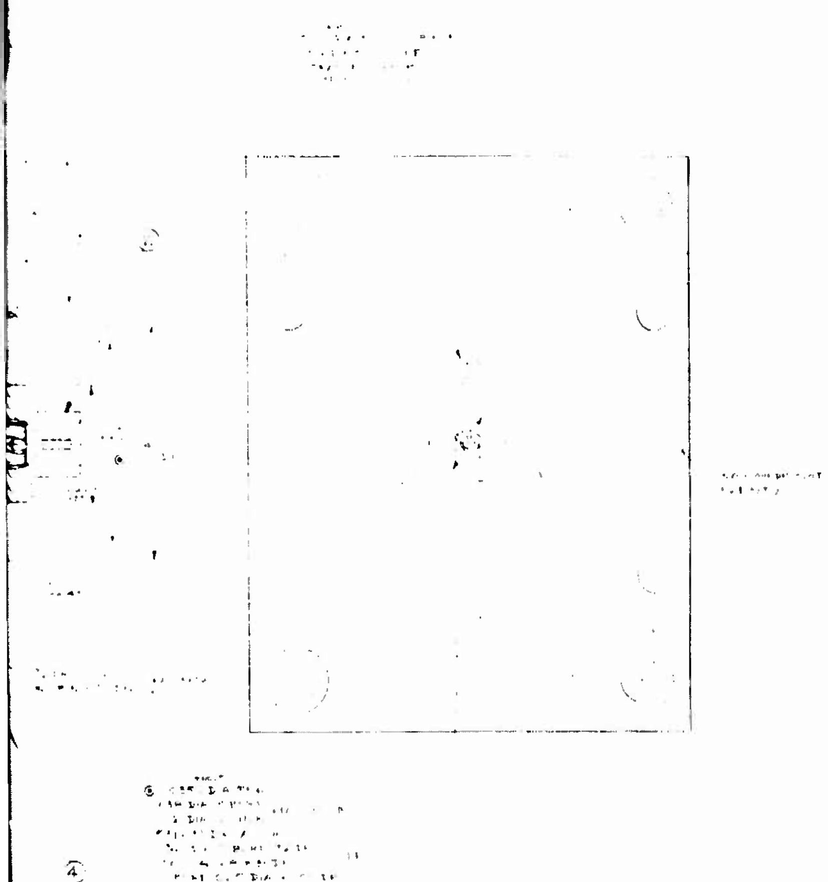
2. TAP THRU MOLD PART 16, TAP ITEM NO 9 3/8-16 x .50 DEEP, JAM FIT ITEM NO. 9

3. 1/4-28 THREAD 1 END ITEM NO. 12

4. ⓪ CONCENTRIC WITHIN .001 T.I.R.

2

REVISIONS



VIEW A-A ITEM NOS 1, 5 & 6 REMOVED

ITEM NO	QTY REQ	CODE IDENT	PART NUMBER	SPECIFICATION NO	NOMENCLATURE
12	1		[illegible] OD x .049 WALL x 5 [illegible] LG		ALUM TUBE (6061-T6)
11	1		[illegible] ID x .070 W, PARKER # 2-19		"O" RING
10	1		[illegible] 16 x 1.00 LG		SOC. HD SET SCR
9	1		[illegible] x 9.00 LG		HEX H.R. STL 1020
8	3		[illegible] 20 x [illegible] LG		SOC HD. CAP SCR
7	3		[illegible] 20 x 1¼ LG		SOC HD CAP SCR
6	1		53593-10023-1		STRIPPER
5	3		53593-10024-1		ROD
4	1		53593-10022-1		CAVITY
3	1		53593-10020-1		SEGMENTS
2	1		53593-10021-1		INLET
1	1		53593-10019-1		CORE
					MOLD ASS'Y

PARTS LIST

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES AFTER PLATING
TOLERANCE
ANGLES ± [illegible]
DECIMAL ±.01 (2 PLACE) ±.005 (3 PLACE)
MATERIAL.

CONTRACT NO
COCKEYSVILLE, MD.
DRAWN R.C. [illegible]
CHECK C. [illegible]
STRESS
DESIGN
ENGINEERING
PROJECT
DESIGN ACT APP
APPROVAL DATE

MOLD ASSEMBLY
20 MM CASE

SIZE F CODE IDENT NO 97384 53593-10025
SCALE SHEET 1 OF 1

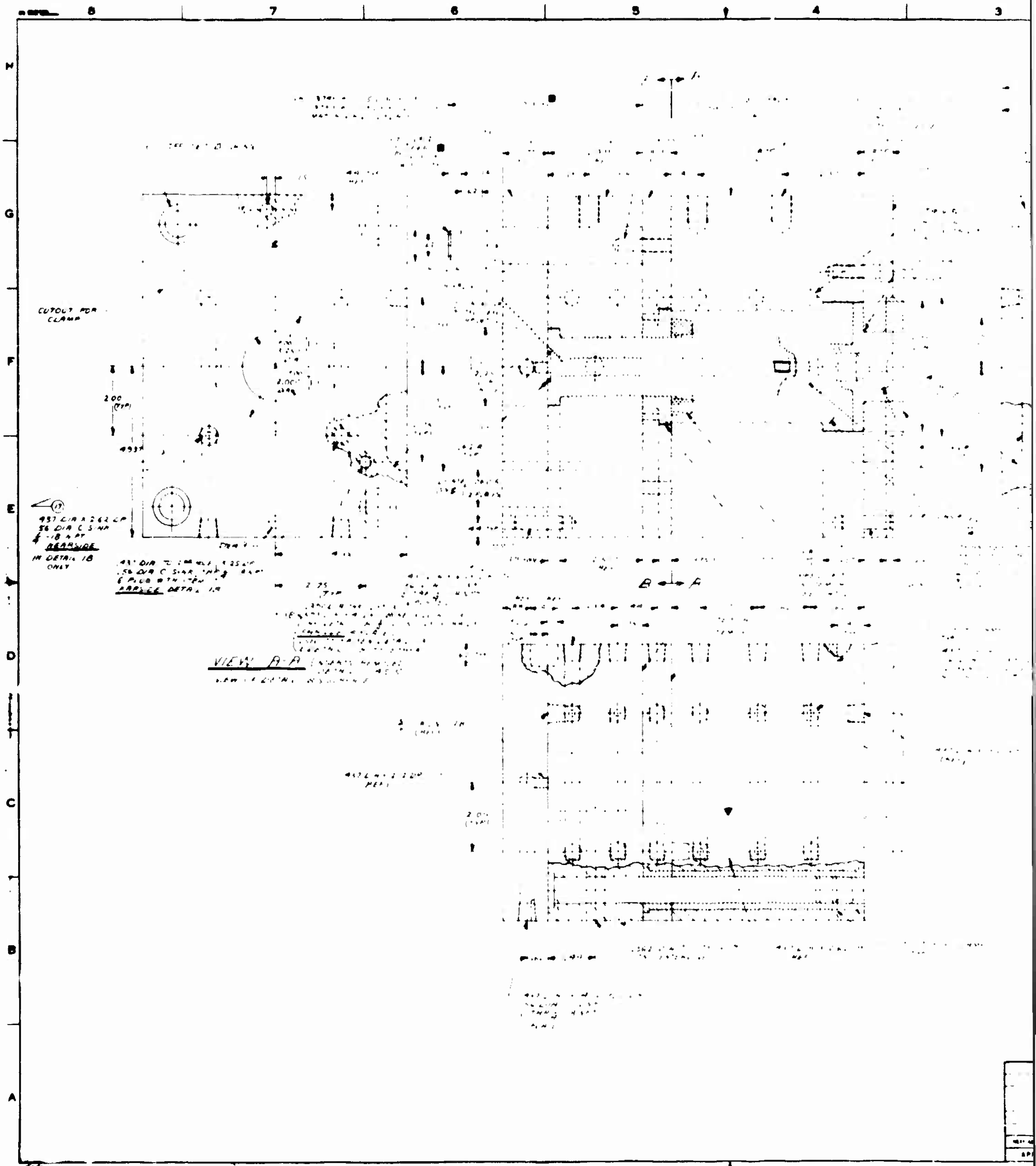
(The reverse of this page is blank)

APPENDIX IV

30MM MOLD DRAWINGS

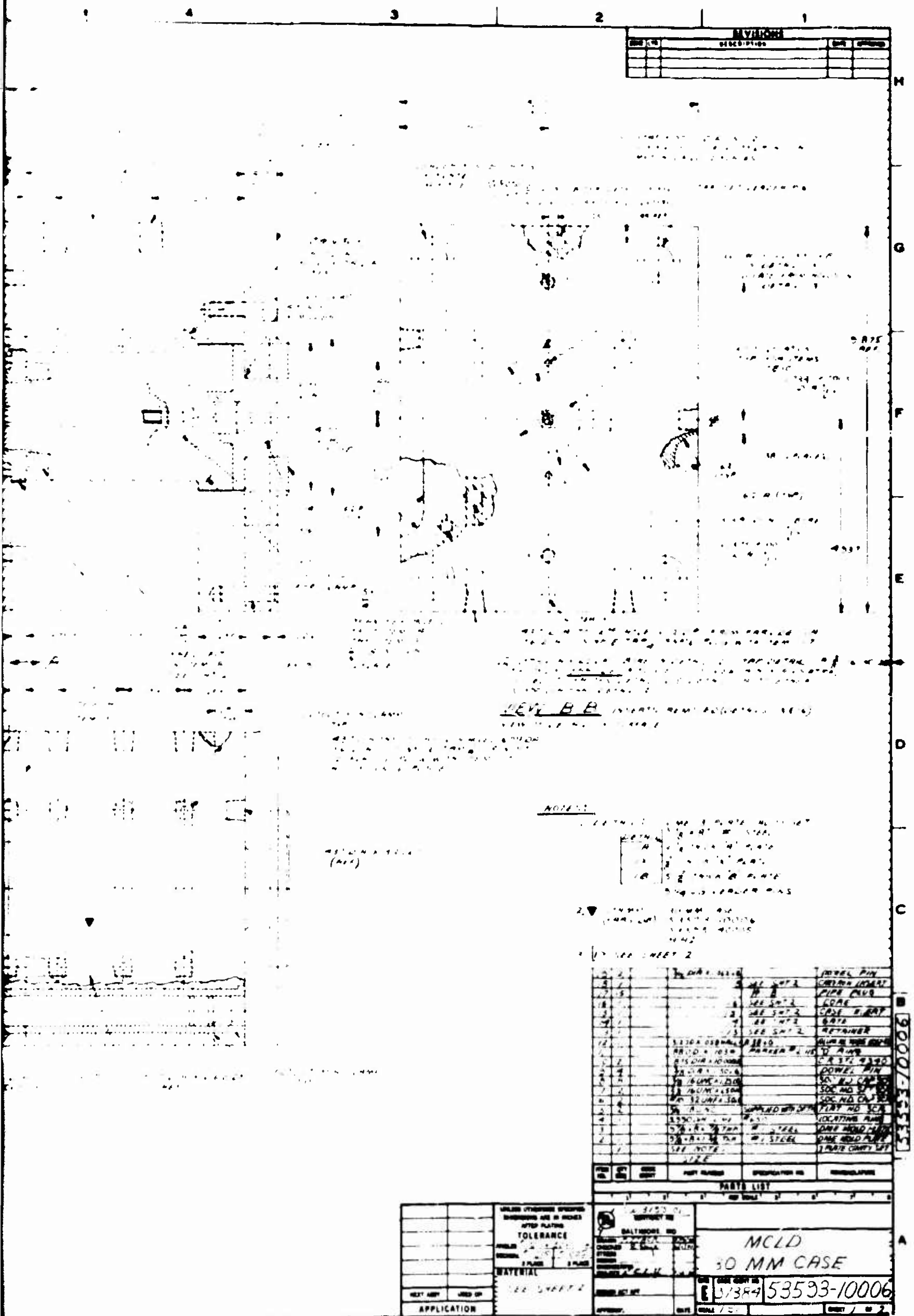
53593-10006 Sheets 1 and 2

(The reverse of this page is blank.)

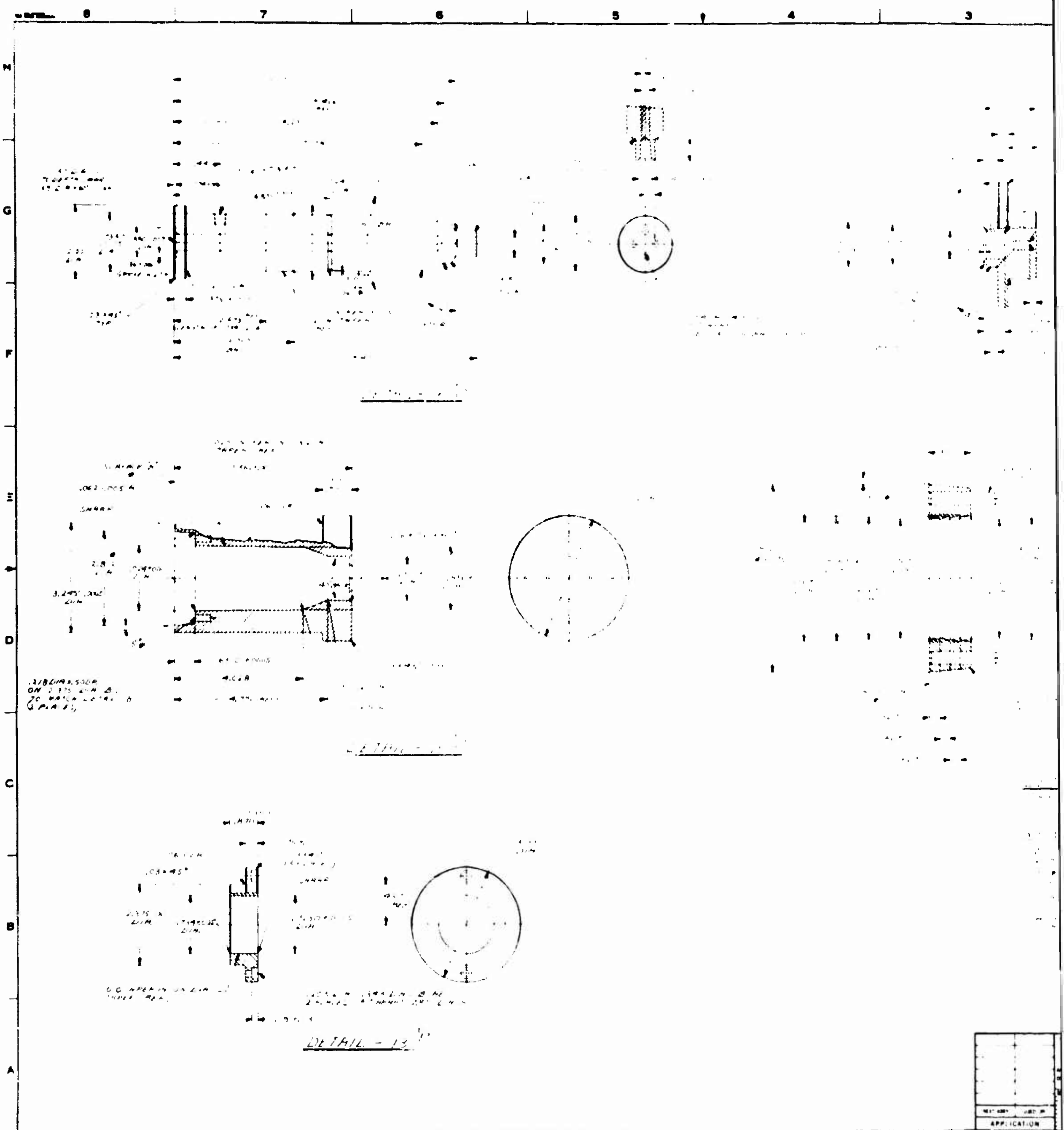


(The reve

2

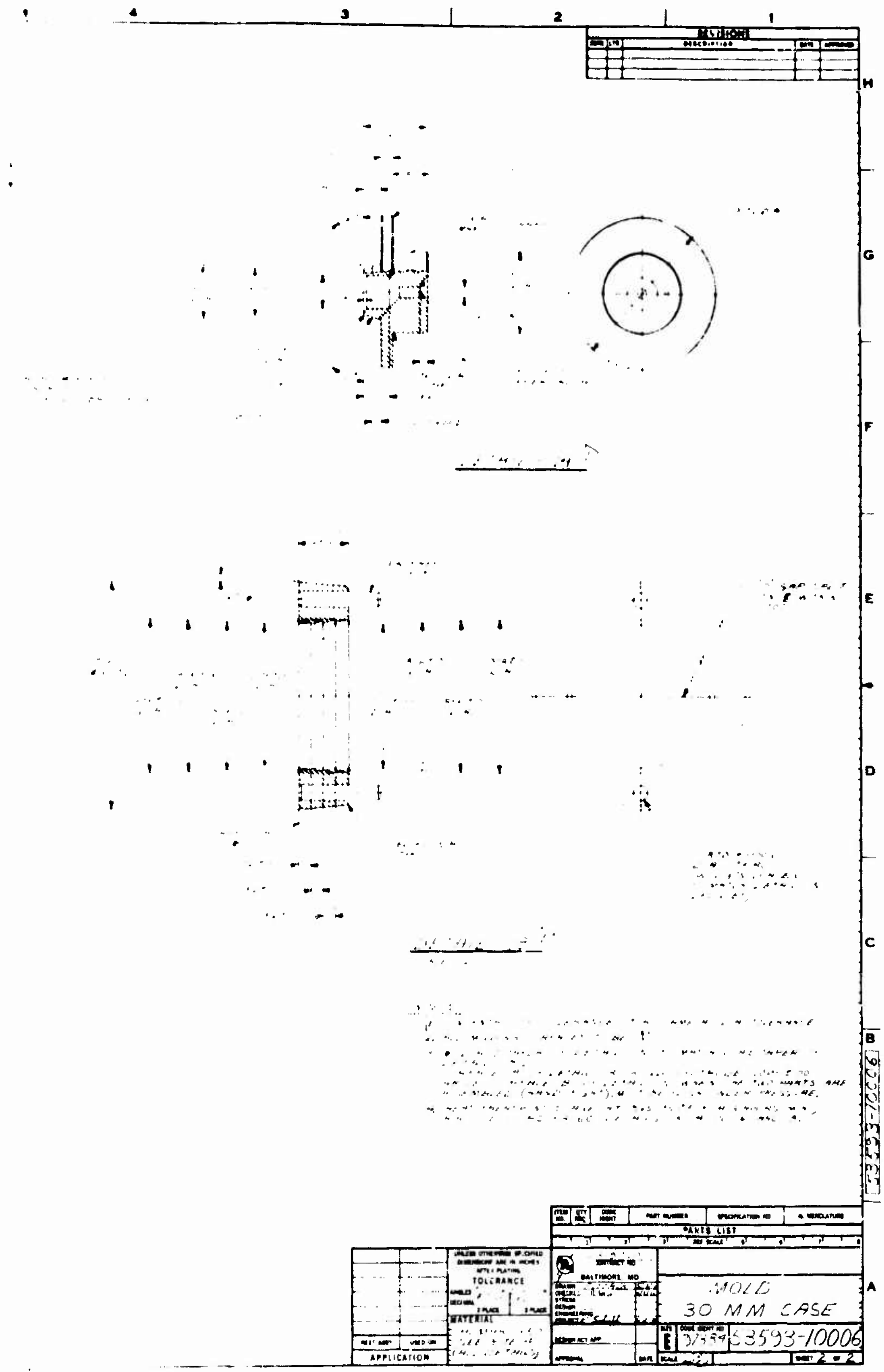


(The reverse of this page is blank)



(The reverse o

2



(The reverse of this page is blank)

APPENDIX V

MANUFACTURER'S ADDRESSES

ADHESIVES MANUFACTURERS

Armstrong Products Company, Inc.
Argonne Road
Warsaw, Indiana 46580

The Biggs Company
1547 Fourteenth Street
Santa Monica, California 90404

Dow Corning Corporation
Midland, Michigan 48640

H. B Fuller Company
59 Brunswick Avenue
Edison, New Jersey 08817

General Electric
Silicone Products Department
Waterford, New York 12188

Smooth-On, Inc.
1000 Valley Road
Gillette, New Jersey 07933

Thiokol Chemical Corporation
780 North Clinton Avenue
Trenton, New Jersey 08607

PLASTICS MANUFACTURERS

E. I DuPont DeNemours and Company, Inc.
Plastics Department
Wilmington, Delaware 19898

Eastman Chemical Products, Inc.
P. O. Box 95
Fort Washington, Pennsylvania 19034

Fiberfil
1701 North Heidelback
Evansville, Indiana 47717

General Electric Plastic's Department
One Plastics Avenue
Pittsfield, Massachusetts 01201

Hüls
Division of Henley and Company
202 East 44th Street
New York, New York 10017

Liquid Nitrogen Processing Corporation
412 King Street
Malvern, Pennsylvania 19355

Thermofil, Inc.
884 Railroad Street
Ypsilanti, Michigan 48197

APPENDIX VI

RECORD OF TEST FIRINGS AS RELATED TO MOLD
CHANGES FOR 20MM PLASTIC/ALUMINUM
CARTRIDGE CASE

TABLE VI-1. TEST FIRINGS AS RELATED TO MOLD CHANGES FOR 20MM PLASTIC/ALUMINUM CARTRIDGE CASE

MOLD CHANGE	DATE	REMARKS	PLASTICS TESTED EACH CHANGE				NUMBER FIRED PRIOR TO NEXT CHANGE			RESULTS
			PLASTIC	PER-CENT GLASS	DESIGNATION	*	-65°F	AMBIENT+	160°F	
Thin Walled Case	March 1970	Case design at the start of development.	66 Nylon	40	RF-1008	L	9	119	-	
			612 Nylon	43	Zytel 77G43	D				
			Polyethylene	None	Alathon	D				
			Polyethylene	30	Alathon	D				
Forward Case Wall Rein-forced	June 1970	Forward case wall made thicker to resist link squeeze. (Refer to Figure 10)	612 Nylon	43	Zytel 77G43	D	12	43	3	Case splits related to link squeeze were eliminated.
			Polycarbonate	None	Lexan 191	G				
Mold Gating Improved	July 1970	Gating cavities enlarged for better flow. (Refer to Figures 11 and 12)	610 Nylon	40	G 12/40	F	147	112	3	The visible flow lines in the case were reduced.
			612 Nylon	None	Zytel 151	D				
			↓	25	Zytel 151	D				
				33	Zytel 77G33	D				
				43	Ztyel 77G43	D				
			612 Nylon	50	QF-100-10	L				
			612 & 6 Nylons	33	Zytel 151 and 211	D				
			Polycarbonate	None	Lexan 141	G				
			↓	None	Lexan 191	G				
				None	Lexan 500	G				
			Polycarbonate	40	Lexan 500	G				
Case Taper Modified	Jan. 1971	Forward case taper changed to 39° - 30' included angle to match M61 chamber	612 Nylon	43	Zytel 77G43	D	86	65	33	Neck failures were nearly eliminated and the cold cracking rate was reduced from 70 percent to 40 percent.
			612 Nylon	45	IS-1009	L				

* Manufacturers

D = DuPont F = Fiberfil G = G.E. T = Thermofil
L = LNP H = Hüls E = Eastman

\+ Tests at ambient temperatures include both Mann barrel and M61 firings.

TABLE VI-1. TEST FIRINGS AS RELATED TO MOLD CHANGES FOR 20MM PLASTIC/ALUMINUM CARTRIDGE CASE (Concluded)

MOLD CHANGE	DATE	REMARKS	PLASTICS TESTED EACH CHANGE				NUMBER FIRED PRIOR TO NEXT CHANGE			RESULTS
			PLASTIC	PER-CENT GLASS	DESIGNATION	*	-65°F	AMBIENT +	160°F	
New Mold Core and Gating System	Sept. 1971	The mold was gated from the front of the case and the retention bead was molded in its final configuration. (Refer to Figure 15)	612 Nylon 612 Nylon Modif. 612 Nylon Type 12 Nylon Polycarbonate Polycarbinate Polyester Polyester	43 43 50 30 4 8 None 20	Zytel 77G43 FE5024 FE5030 L1930 Lexan 141 Lexan 141 PTMT 6PRO PTMT 6G91	D D D H G G E E	332	17	38	Neck failures were completely eliminated with the molded retention bead.
Thicker Case Wall	July 1972	The case wall was made thicker aft of the reinforced section to eliminate the transition between thick and thin sections. (Refer to Figure 17)	Fluoropolymer Fluoropolymer 612 Nylon Type 12 Nylon	None 20 50 50	Tefzel 200 Tefzel 2004 FE 5030 N9-5000-FG	D D D T	90	-	-	High temperature tensile failures in the forward case wall were eliminated.
Case Diameter Increased	Aug. 1972	The "B" dimention (Refer to Figure 18) was increased for better chamber fit.	612 Nylon Type 12 Nylon Polycarbonate Polycarbonate Polyester	50 50 None 10 30	FE 5030 N9-5000-FG Lexan 191 Lexan 500 Valox 420	D T G G G	168	5	19	Cold cracking incidence was reduced with most materials and eliminated with type 12 nylon/50 percent glass.

* Manufacturers

D = DuPont F = Fiberfil G = G.E. T = Thermofil
L = LNP H = Huls E = Eastman

+ Tests at ambient temperatures include both Mann barrel and M61 firings.

(The reverse of this page is blank)

INITIAL DISTRIBUTION

HQ USAF (RDQRM)	2
HQ USAF (SAMID)	1
HQ USAF (XOXFCM)	1
HQ USAF (XOOW)	2
HQ USAF (RDPA)	1
AFSC (IGFG)	1
AFSC (DLTW)	1
AFSC (SDWM)	1
ASD (TWT)	1
ASD (TWD)	1
ASD (ENYS)	1
ASD (ENVW)	1
ASD (ENWS)	2
FTD (PDXA)	1
AFML (LNC)	1
AFML (LPH)	1
AFML (LAM)	1
AFAL (LVA)	1
AFFDL (FBS)	1
TAC (DMW)	1
TAC (DRFM)	1
TAC (DMAN)	1
SAC (OAI)	1
SAC (DMW)	1
WRAMA (MMEBL)	1
CIA (CRE/ADD)	2
AEDC (ARO,INC)	1
AFWL (DOGL)	1
AF SPEC COMM CNTR (SUR)	2
AUL (AUL-LSE-70-239)	1
CH R&D (CRDAM)	1
REDSTONE SCI INFO CNTR	2
USA WPNS COMD AMSWEREW	3
USA MATR SYS ANAL AGCY AMXRD-AS	1
USA MATR SYS ANAL AGCY AMXRD-AA	1
USA MATR SYS ANAL AGCY AMXRD-DB	1
USA ABERDEEN R&D CTR	1
FRANKFORD ARS ATTN: LIB	1
PICATINNY ARS SMUPA-RT-S	1
NAV AIR SYS COMD CODE AIR 350B	1
USN WPNS LAB CODE TR	1
USN ORD LAB TECH LIB	1
USN ORD LAB CODE 730	2
NAV ORD STN TECH LIB	1
NAV WPNS STN CODE 64	1
NAV SYS CTR NEWPORT LAB	1
SAFETY RSCH CTR	1
USN WEA CNTR CODE 753	2
USN WEA CNTR CODE 4585	1
USN WPNS EVAL FAC CODE WE	1
57 FTR SPN WG (FWOA)	3
NAV AIR SYS COMD CODE AIR 5323	1
NAV AIR SYS COMD CODE AIR 5324	1
CH NAV OPNS OP-722	1
USN RSCH LAB CODE 2027	1
USN RSCH LAB CODE 5180	1
OFF NAV RSCH CODE 473	1
NASA STINFO FAC	1
U OF CA LRL CHEM DEPT	1
U OF CA LRL TECH INFO DEPT	1
LOS ALAMOS SCI LAB	1
CHEM PROP INFO AGCY	2
BATTELLE MEM INST	1
INFRARED INFO ANAL CTR	1
INST DEF ANALY	1
SANDIA CORP TECH LIB	2
SANDIA CORP DIV 2341	1
RAND CORP LIB-D	1
ARMY MATRL COMD AMCRD-BN	1
USAF TAC FTR WPNS CNTR	1
HARRY DIA LABS	1
DDC	2
CINCUSAFE (DMW)	1
CINCUSAFE (OA)	1
CINCPACAF (DMWXE)	4
AEC LIB	1
CH R&D (ORCD)	1
BRL (AMXBR-XBL)	1
BRL (AMXRD-BTL)	2
BRL ATTN: RL MCCOY	2
BRL TECH LIB	1
WATERVLIET ARS	3
USNOL AERO DEPT	1
NAV WPN LAB ATTN DR KEMPER	1
NAV WPN CTR CODE 50704	1
NAV WPNS CTR CODE 5015	3
FRANKFORD ARS SMUFA-J-7300	1
FRANDFORD ARS SMUFA-J-5300	1
AFIT TECH LIB	1
4525 FTR WPNS WG (FWOA)	3
USA R&D CTR CMXRD-AD	1
NAV ORD SYS CODE ORD-0332	1
NAV WPN CTR CODE 4063	1
DIR RSCH LAB AERO RSCH GP	1

INITIAL DISTRIBUTION (Concluded)

SANDIA CORP ORG NO 9322	1
U OF NOTRE DAME	1
PICATINNY ARS ATTN AA LOEB	3
AFSC TECH LIB	2
PLASTEC	3
HQ PACAF (IGY)	1
CDCLO/DO	1
WE	1
USAFTAWC (AY)	3
DL	1
DLB	1
DLD	1
DLY	1
DLR	1
DLOSL	2
DLRV	1
DLRD	1
DLRW	1
DLIM	1
DLII	1
DLDL	20
DLDG	20

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) AAI Corporation P. O. Box 6767 Baltimore, Maryland 21204	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3 REPORT TITLE

DEVELOPMENT OF 20MM AND 30MM PLASTIC/ALUMINUM CARTRIDGE CASES

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report - 1 March 1970 to 30 September 1972

5 AUTHOR(S) (First name, middle initial, last name)

Matthew G. Popik
Robert W. Schnepfe

6 REPORT DATE	7a. TOTAL NO OF PAGES	7b. NO OF REFS
October 1972	88	

8a. CONTRACT OR GRANT NO F08635-70-C-0067 b. PROJECT NO 670A c. Task No. 02 d. Work Unit No. 027	9a. ORIGINATOR'S REPORT NUMBER(S) ER-7250 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFATL-TR-72-201

10 DISTRIBUTION STATEMENT

Distribution limited to U. S. Government agencies only; this report documents test and evaluation; distribution limitation applied October 1972 . Other requests for this document must be referred to the Air Force Armament Laboratory (DLDG), Eglin Air Force Base, Florida 32542.

11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
Available in DDC	Air Force Armament Laboratory Air Force Systems Command Eglin Air Force Base, Florida 32542

13 ABSTRACT

Basic feasibility was established for the 20mm and 30mm plastic/aluminum cartridge cases under this program. The case design consists of a plastic body joined mechanically to an aluminum base forming a composite assembly. Work on the 30mm case was limited to Mann barrel firings while the 20mm case was fired successfully in both a Mann barrel and the M61 automatic gun at a rate of 4300 rounds per minute. Test firings of the 20mm case in the M39 gun, however, were unsuccessful. The effort on the 20mm case progressed into a development program including high and low temperature firings in the M61. Satisfactory case performance has been established at the temperature extremes (160°F and -65°F) and at ambient temperatures with the case design being developed as far as possible within the scope of this contract.

DD FORM 1473

UNCLASSIFIED

Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Plastic/Aluminum Cartridge Cases						
M61 Cannon						
30mm Cartridge Case						
20mm Cartridge Case						
Type 12 Nylon						
Mann Barrel						
M61 Automatic Gun						
M103 Brass Cartridge Case						